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TABLES FOR ESTIMATING AGES AND BIRTH DATES OF COTTONTAIL RABBITS

With Suggestions for Handling Lenses

WILLIAM R. EDWARDS

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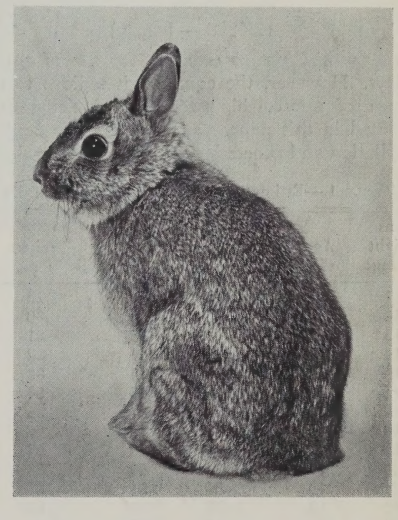

ILLINOIS NATURAL
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STATE OF ILLINOIS
Department of Registration and Education
NATURAL HISTORY SURVEY DIVISION

TABLES FOR ESTIMATING AGES AND BIRTH DATES OF COTTONTAIL RABBITS, With Suggestions For Handling Lenses

William R. Edwards

Lord (1959) first presented the concept of estimating the ages of cottontail rabbits (*Sylvilagus floridanus* spp.) on the basis of the dry weight of the eye lens. He gave a graphic representation of the relationship between age (x) and the dry weight of the lens (y) for approximating the ages of cottontails in days (Lord 1959:360). Dudzinski and Mykytowycz (1961:159), using Lord's data (1959:359), reduced the relationship of dry lens weight to age for cottontails to the algebraic form

$$\log_{10} y = 2.4890 - \left[\frac{68.7927}{(x + 41)} \right]$$

Manipulation of this equation to the form

$$x = \frac{68.7927}{(2.4890 - \log_{10} y)} - 41$$

allows the biologist to estimate the age of a cottontail in days. However, the equation is tedious to use with samples of appreciable size. Consequently, the tables presented in this paper were prepared to facilitate the compilation and processing of cottontail lens data.

Estimated ages in days were computed for lens weights of 11–210 mg (Table 1). Because of the relatively low precision of the estimating equation, as suggested by the work of Dudzinski and Mykytowycz (1961:158), there is little justification for using the equation for growth of cottontail lenses in estimating ages beyond the first-year class. When one knows the dry weight of a lens in milligrams, it is a simple matter to find that weight in one of the columns in Table 1 and to read the estimated age in days in the adjacent column.

Statistics gathered at the Illinois Natural History Survey suggest a high degree of bilateral symmetry in weight between a rabbit's lenses. We now believe that the difference in weight between lenses of a pair is primarily the result of sloughing off of tissue of one or both during handling. Thus, we suggest that only the weight of the heavier lens of each pair be used in estimating age even when both lenses are in apparently good condition.

Table 2 was prepared to simplify determination of an estimated date of birth after an estimate of age has been obtained. In this table days of the year are num-

TABLE 1.—Estimated ages of cottontails from dry weights of eye lenses.

Lens Weight in mg	Age in Days	Lens Weight in mg	Age in Days	Lens Weight in mg	Age in Days	Lens Weight in mg	Age in Days	Lens Weight in mg	Age in Days	Lens Weight in mg	Age in Days
11	7	45	41	79	75	112	115	145	169	178	247
12	8	46	42	80	76	113	117	146	171	179	250
13	9	47	43	81	77	114	118	147	173	180	253
14	10	48	44	82	79	115	120	148	175	181	256
15	11	49	45	83	80	116	121	149	177	182	260
16	12	50	46	84	81	117	122	150	179	183	263
17	14	51	47	85	82	118	124	151	181	184	266
18	15	52	48	86	83	119	125	152	183	185	269
19	16	53	49	87	84	120	127	153	185	186	272
20	17	54	50	88	85	121	128	154	187	187	276
21	18	55	51	89	86	122	130	155	189	188	279
22	19	56	52	90	88	123	131	156	191	189	283
23	20	57	53	91	89	124	133	157	194	190	286
24	21	58	54	92	90	125	134	158	196	191	290
25	22	59	55	93	91	126	136	159	198	192	293
26	23	60	56	94	92	127	138	160	200	193	297
27	24	61	58	95	94	128	139	161	203	194	301
28	25	62	58	96	95	129	141	162	205	195	304
29	26	63	59	97	96	130	142	163	208	196	309
30	27	64	60	98	97	131	144	164	210	197	313
31	28	65	61	99	98	132	146	165	212	198	317
32	29	66	62	100	100	133	147	166	215	199	321
33	30	67	63	101	101	134	149	167	217	200	325
34	31	68	64	102	102	135	151	168	220	201	329
35	32	69	65	103	103	136	152	169	222	202	334
36	33	70	66	104	105	137	154	170	225	203	338
37	34	71	67	105	106	138	156	171	228	204	342
38	35	72	68	106	107	139	158	172	230	205	347
39	36	73	69	107	109	140	160	173	233	206	352
40	37	74	70	108	110	141	161	174	236	207	357
41	38	75	71	109	111	142	163	175	239	208	362
42	38	76	72	110	113	143	165	176	242	209	366
43	39	77	73	111	114	144	167	177	244	210	371
44	40	78	74								

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bered consecutively and arranged by month. For example, when one knows that a specimen was collected on December 12 (day 346) and was estimated to be 216 days old when collected, one can estimate the date of birth by subtracting 216 from 346, in this instance day 130, or May 10. Data on estimated dates of birth permit computation of a mean estimated birth date and its standard error and thereby facilitate testing of differences in these parameters among populations or comparison with a normal as a means of determining differences in age structure.

SUGGESTIONS FOR HANDLING COTTONTAIL LENSES

1. Care must be taken to remove eyeballs intact (Fig. 1). When an eyeball is ruptured, frequently at the

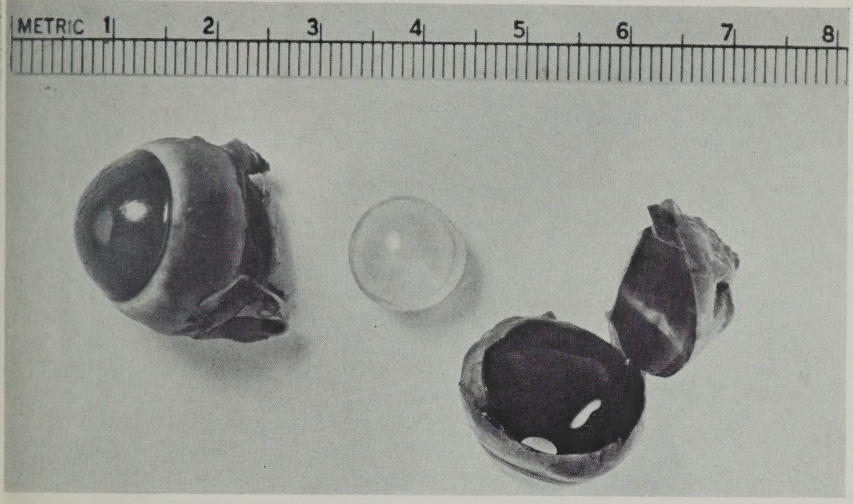

Fig. 1. — Cottontail eye intact and eye with lens removed. The eyeball at left is in the proper intact condition after fixation in a 10-percent formalin solution. The fixed lens is shown after removal but before drying.

TABLE 2.—Figures for estimating birth dates of cottontails from the estimated age in days.

Day of Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

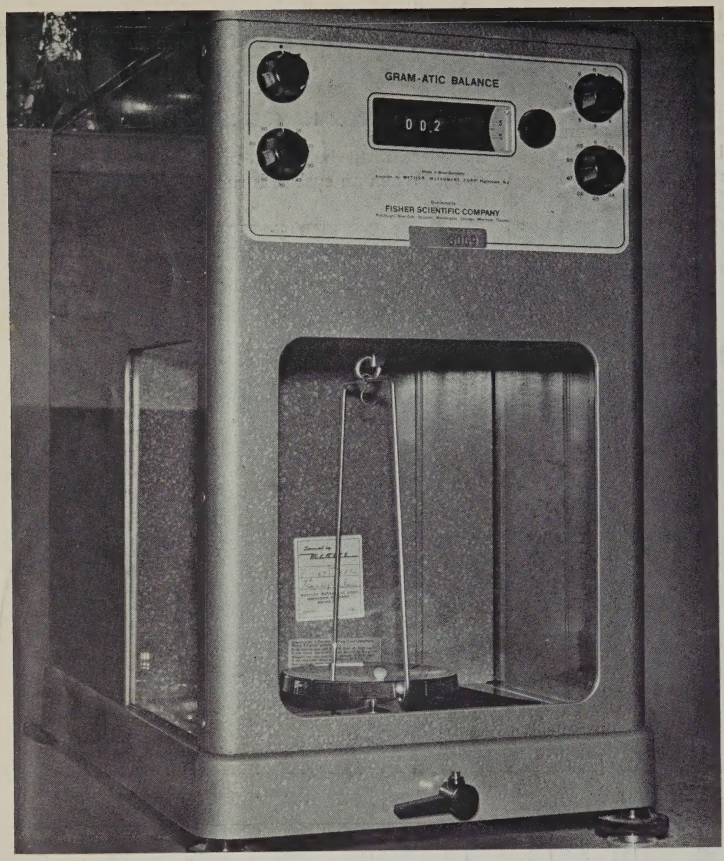

Fig. 2.—Mettler Gram-Atic balance. This type of balance is suggested for weighing cottontail lenses for reasons of speed and accuracy.

connection to the optic nerve, the vitreous humor is usually lost and the eyeball collapses around the lens. If this occurs, the outer fibers of the lens adhere to the inner coatings of the eyeball during fixation and are lost when the lens is removed. Discard damaged eyeballs.

2. Lenses should not be allowed to freeze prior to or during fixing. Freezing frequently results in lens tissue being sloughed off.

3. Lenses should be fixed in a *buffered* 10-percent formalin solution as soon as possible after the animal is collected.

4. Ten days should be allowed for fixing lenses in the buffered 10-percent formalin solution. Our data suggest that no adverse effects occurred when eyeballs were left in the fixing solution as long as 120 days.

5. After fixing, lenses should be dried for about 1 week at 80° C. in an oven equipped with a fan for circulation of air. For an unknown reason some lenses and batches of lenses do not fix and dry properly. These lenses differ in appearance from those properly fixed, and with a little experience "bad" lenses can be quickly recognized. Discard any lens which evidences sloughing off of tissue or appears atypical in color or shape.

6. Because lenses are hygroscopic, they should be weighed immediately after removal from the drying oven or stored immediately in suitable airtight, moisture-free containers.

7. Analytical balances of the Mettler type (Fisher Scientific Company, Pittsburgh, Pa.) (Fig. 2) are probably the easiest and most rapid to use and the most reliable now available for weighing lenses; Roller-Smith precision balances (Roller-Smith Company, Newark, N. J.) have also proved satisfactory.

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Use of Feather Minerals as Biological Tracers to Determine the Breeding and Molting Grounds of Wild Geese

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HAROLD C. HANSON
ROBERT L. JONES

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Fig. 1.—Hudson and James Bays, showing locations of study areas and features discussed in the text.

COVER PHOTOGRAPH: Nesting pairs of lesser snow geese on Kendall Island, delta of the Mackenzie River, N.W.T.

Use of Feather Minerals as Biological Tracers to Determine the Breeding and Molting Grounds of Wild Geese

HAROLD C. HANSON and ROBERT L. JONES[1]

MOST POPULATIONS AND SUBPOPULATIONS of wild geese are distributed on their breeding grounds in discrete units that occupy distinct physiographic and geologic areas. The possibility that feathers of these various populations contain an assortment of minerals bearing some relationship to the occurrence of elements in the nutrient chain—parent rocks, soils, waters, and food plants—of the breeding grounds was suggested by studies made of the mineral content of the body and feathers of ruffed grouse (*Bonasa umbellus*) in New Hampshire.[2] It was found that a grouse could be associated with one of the four geological areas in the state by the content of minerals occurring in its tail feathers.

After we had confirmed, from studies beginning in 1965, that a similar relationship existed between the minerals in the primary feathers of all the races of Canada geese examined[3] and the minerals in the ecosystems of their breeding grounds (Illinois Natural History Survey 1966), the study was extended to all species and races of wild geese breeding in or migrating into North America. In this report the analytical techniques used are described and the types of results obtained are illustrated by data for two populations of blue and lesser snow geese (*Anser caerulescens caerulescens*)[4] which nest adjacent to Hudson Bay.

Waterfowl nesting in temperate and more northerly portions of the northern hemisphere undergo a precipitous molt of primary and secondary wing feathers. The molt occurs in breeding geese about 7–10 days after the young have hatched and about an equivalent time earlier in the nonbreeding birds. The time required for growth of new flight feathers is directly related to the size of the bird. In Canada geese (*Branta canadensis*), which range in weight from 3 to 18 pounds, the flightless period varies from about 24 to 42 days (Hanson 1965 and unpublished). For lesser snow geese this period is about 25 days.

The primary wing feathers were selected for analysis because their growth must be complete before the birds leave their natal area or, in the case of nonbreeding birds that have made a molt migration, their molting area. In contrast, the replacement of tail and body feathers may continue well into autumn and winter.

The likelihood of a distinctive regional profile of minerals being incorporated into the protein matrix of the feather is increased by the dramatic degradation and synthesis of muscle and bone that take place during the period of principal growth of the wing feathers. A recent study of Canada geese (Hanson 1962) has shown that by the midperiod of the molt the sternal muscles lose 25–41 percent of their weight and the leg muscles increase in weight 41–57 percent, depending on age and sex. By the time flight is resumed, the weights of these muscle groups are almost back to normal. The degradation of the sternal muscles appears to be a survival-related evolutionary development whereby amino acids, particularly the sulfur amino acids, are made available for rapid feather growth. The hypertrophy of the leg muscles, however, reflects their temporarily increased use.

In addition to these dramatic changes in mass of the muscles, dynamic changes in the mineral metabolism of the muscle tissues also take place (Hanson and Johnson, unpublished). The deposition and high turnover of medullary bone during egg laying in birds is well documented (Sturkie 1965: 491–501); less well understood is the osteoporosis of the long bones of the leg, particularly the tarsi, that takes place during molt (Meister 1951; Hanson unpublished).

As a result of these various degradational processes, a high turnover of some minerals and selective conservation of others is implicit during molting and breeding cycles.

ACKNOWLEDGMENTS

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[1]Dr. Harold C. Hanson is a Wildlife Specialist at the Survey. Dr. Robert L. Jones is a Soil Mineralogist at the University of Illinois College of Agriculture.

[2]Studies by Robert A. McCullough and C. L. Grant in 1952-1953 in connection with Pittman-Robertson—Dingell-Johnson projects involving laboratory analyses of fish and game and their foods.

[3]Studies in progress by the senior author indicate the existence of 20, rather than the currently recognized 12, races of Canada geese.

[4]Most authorities now recognize the blue goose and lesser snow goose as color phases of the same subspecies.

eries and Wildlife who called his attention to the grouse studies of McCullough and Grant in 1962 during discussions of taxonomic problems in Canada geese.

For logistic support and aid in collecting specimens, we are grateful to Harry G. Lumsden, John Lessard, and C. E. Perrie of the Ontario Department of Lands and Forests; Eugene F. Bossenmaier of the Manitoba Department of Mines and Natural Resources; and G. C. Wilson, Rocket Range Officer, National Aeronautics and Space Administration, at Churchill, Manitoba. Dr. F. Graham Cooch of the Canadian Wildlife Service advised us on the origin of the blue and lesser snow geese collected at Fort Severn, Ontario.

We are indebted to Emil Marcusiu, University of Illinois, and Leland Herzberger, now with the U.S. Bureau of Sport Fisheries and Wildlife, for the excellence of their laboratory work. Dr. Robert E. Johnson, Dr. S. Charles Kendeigh, and Dr. C. Ladd Prosser of the University of Illinois kindly reviewed the manuscript.

Photographs for the cover and Fig. 2 were made possible through the cooperation of James G. King and Harold H. Burgess of the U.S. Bureau of Sport Fisheries and Wildlife.

STUDY AREAS, MATERIALS, AND METHODS

The blue and lesser snow geese for which data on feather minerals are reviewed here breed adjacent to Hudson Bay at Cape Churchill, Manitoba, and on Southampton Island, N.W.T. (Fig. 1).

The Cape Churchill colony is unique in several respects. It is of very recent origin, possibly dating from 1962 when Harry G. Lumsden and the senior author observed a few dozen birds in the area. We know of no records of the existence of a colony of appreciable size prior to that year. In 1966, aerial photographs of a large percentage of the flightless adults and their downy young, and estimates of the remainder, indicated that the colony contained 5,000–6,000 geese. The feeding range of this colony is restricted to a roughly triangular area that flanks Hudson Bay for a distance of about 13 miles west of the Cape and extends for 7 miles south of it.

All of the major colonies of lesser snow and blue geese in the Canadian Arctic occupy areas of earlier marine submergence, but they are locally situated either on braided river mouths or on delta islands. Although subject to tidal flooding along the seaward edges, these areas are constantly flushed by fresh water. In contrast, emergence of the Cape Churchill colony site from the waters of Hudson Bay may be as recent as 1,000 years ago.[1] The area is low, subject to periodic extensive tidal flooding, and drained only by a few small streams. The geese feed near the coast, both within the tidal zone and in the adjacent salt marsh.

The soils of the area and the silt and clay sediments in which they developed are highly calcareous, having been derived from calcareous Silurian sedimentary rocks underlying the Cape.

The blue and lesser snow geese that feed along the south coast of Hudson Bay each autumn in the vicinity of Fort Severn, Ontario, originate from two colonies on Southampton Island—one at the apex of East Bay and the other at the mouth of the Boas River which empties into the Bay of Gods Mercy (F. Graham Cooch, personal communication). Probably the wing samples that we studied from geese shot at Fort Severn chiefly represented the much larger, Boas River colony.[2] Geologically, both areas are similar, being underlain by limestone of Ordovician and Silurian ages (Armstrong 1947). According to Manning (1942), the nests of this colony "are situated almost entirely on grassy islands in the mouth of the Boas River. . . . At its mouth, the river is at least two miles wide, and in July is so shallow that it can be crossed in knee boots; but during the spring it is greatly swollen. On both banks the river is bounded by about eight miles of flat marshland which terminates in disintegrated limestone ridges."

In our studies only the vane portions of the primary feathers were used in the analyses because they were found to be more highly mineralized than the shaft. The basal quarter of the vane was also excluded because part of this portion of the feather is grown after the goose has regained the power of flight (Hanson 1962) and could possibly, although unlikely, have left the breeding or molting area. In this case it would be possible for a somewhat different mineral pool to be incorporated into the basal portion of the feathers.

To facilitate washing, the remaining portions of the primary feathers were cut transversely into 1½-inch pieces. These were washed with distilled water by shaking in 250 ml conical flasks for at least 4 hours and then rinsed several times with distilled water. The flasks and contents were then drained of excess water and dried in an oven held at 60° C. for at least 24 hours. Approximately 1 gram of the dried vane was trimmed free of the shaft and placed in a 50-ml Vycor crucible.

Analytical determinations were performed with a Jarrell-Ash direct reading emission spectrograph on an acid solution (containing 4.5 percent HCl and 1.5 percent HNO_3, both by volume, and 1 percent lithium as LiCl) of the dry-ashed (500° C.) sample. A rotating-disc solution technique with a-c spark excitation was used with lithium as an internal standard. The content of each element was estimated from working curves obtained from reference plant samples.

[1] Aerial observations indicated that the main feeding grounds of this colony lie well within the 25-foot elevation level (Cape Churchill Sheet, 54 K, 4 mile-1 inch topographic series, Canadian Department of Mines and Technical Surveys). This date assumes a rate of postglacial uplift of 75 centimeters per 100 years (Barnett 1966).

[2] This feather collection undoubtedly contained primaries of a few geese from the colony at Eskimo Point. A definitive report on the biogeochemistry of all breeding colonies, based on birds collected either on their breeding grounds or banded there during the molt and shot elsewhere, is under preparation.

RESULTS AND DISCUSSION

The results of the feather analyses are given in Table 1, and levels of significance (P) for differences between means using the "t" test are tabulated in Table 2.

Few facts of a fundamental physiological nature can be deduced from these data at this time. The slightly higher levels found for most minerals in adults are, however, of interest. Many clear distinctions in mineral concentration can be made between the Cape Churchill and Southampton Island goose populations that are valuable for the practical purpose of determining the origin of a goose. The higher sodium, potassium, calcium, and magnesium values for the Cape Churchill geese reflect close association with the tidal and brackish water conditions and higher content of mineral elements in this environment, whereas the lower values for Southampton Island geese reflect the traditional inland movement to fresh-water areas of these birds after hatch (Bray 1943). Our accumulating data from breeding areas, from which we have ascertained the chemical composition of the soils and food plants as well as feathers of the populations concerned, clearly indicate that the higher values for phorphorus, manganese, silicon, aluminum, and boron in the feathers of the Southampton Island geese must be associated with an intake of food plants, soils, and grit proportionately more abundant in these elements. The invariant nature of zinc and copper in these two populations probably reflects physiological control in environments low in these minerals. In general, the levels of significance (Table 2) for the adults and for the immatures between the two populations are similar; those data showing wide differences reflect variability and wide range in the analyses.

There is a close similarity of values for adults and immatures from each locality (Table 1). This similarity contradicts the possibility that data for adults are not likely to be meaningful because the birds return north with a highly differentiated body pool of minerals and grit in the gizzard after 6–8 months of feeding in other environments. Evidently, the 1–2 months the adults spend on their breeding grounds prior to the molt is sufficient time for a new balance to be achieved between their mineral pool and the new environment. The possibility of genotypical differences between the two populations as a factor in explaining, at least in part, differences found in feather chemistry can also be dismissed because the Cape Churchill population is of very recent origin and was very likely derived from Eskimo Point colony stock (Fig. 1) which in turn is thought to have originated from Southampton Island stocks.

There is little information in the literature on the mineral content of feathers. In his summary of animal nutrition Mitchell (1962:229) was able to cite only Gonnermann (1918) with respect to mineral content

TABLE 1.—Analyses (ppm), standard error of the mean, and range of the analyses of vane portions of blue and lesser snow goose feathers. (Negative values correspond to values less than figures stated. For computation, the negative sign was ignored.)

	Cape Churchill, Manitoba (locally breeding stocks)						*Fort Severn, Ontario (stocks breeding on Southampton Island, N.W.T.)*					
	Adults (N=11)			Immatures (N=5)			Adults (N=18)			Immatures (N=10)		
	Mean	S_x	Range	Mean	S_x	Range	Mean	S_x	Range	Mean	S_x	Range
Na	581	18	445—644	536	30	441—606	237	11	172—315	231	14	160—298
K	670*	191	153—1,623	822**	251	443—1,296	65	14	16—300	43	3	21—54
Ca	1,809	111	1,500—2,800	1,900	141	1,600—2,400	1,417	70	600—2,000	1,310	72	900—1,600
P	204	12	-150—250	200	16	-150—250	264	22	150—500	280	21	200—400
Fe	82	16	10—219	71	8	54—95	189	15	68—314	170	26	78—303
Zn	116	2	106—124	113	3	104—121	117	3	81—130	116	2	103—128
Mg	568	38	450—900	550	39	500—700	342	12	300—500	340	37	300—400
Mn	3.2	0.5	2—8	3.2	0.2	-3—(-4)	5.6	0.8	-2—10	4.6	0.8	-2—9
Cu	7.0	0.3	5—8	7.2	0.7	6—10	6.9	0.4	5—10	6.6	0.3	6—8
Si	1,818	788	-1,000—9,700	1,220	97	-1,100—1,600	2,256	373	-1,000—5,700	3,150	946	-1,000—8,600
Al	21	2.7	-12—78	16	1.1	-14—20	85	9	31—150	83	17	16—174
B	2.6	0.2	4—9	3.4	0.2	3—4	4.8	0.4	3—7	4.3	0.2	4—6

*N=7
**N=3

Table 2.—Values for P comparing adults and immature birds within populations and each age group between populations, blue and lesser snow geese.

	Cape Churchill Adults vs. Immat.	*Fort Severn Adults vs. Immat.*	*2 Areas Adults*	*2 Areas Immat.*
Na	.20	.75	<.01	<.01
K	.71	.35	<.01	<.01
Ca	.64	<.01	.03	<.01
P	.87	.65	.06	.03
Fe	.66	.44	<.01	.02
Zn	.64	.82	.80	.42
Mg	.87	.95	<.01	<.01
Mn	.60	.58	<.01	.22
Cu	.78	.63	.88	.37
Si	.62	.32	.59	.18
Al	.24	.91	<.01	.01
B	.01	.38	<.01	.01

of feathers. The latter found that silicon (as SiO_2) may account for as much as 77 percent of the ash of the primary feathers of ring doves (*Streptopelia roseogrisea*) (presumably captives). We assume that most minerals have been bonded to the protein matrix of the keratin via free charges on the amino acids rather than physical adsorption or exchange on the surface of the feather. Possibly some minerals occur as salts of acids. Certain elements are known to have a competitive and others a reciprocal relationship to organic binding sites; others may be substitutive. We suspect, however, that binding rates of the various ions at the feather follicle (anlage) tend to follow the law of mass action.

In addition to the several recognized ways that minerals in the diet in amounts greater than body needs are excreted—by way of the alimentary canal, kidneys, and the salt or nasal glands (Na^+ only)—it clearly appears that the feather protein is a fourth avenue of excretion of excess minerals. The data for the two snow goose colonies suggest that wild geese maintain normal physiological functions under widely varying rates of mineral intake. No firm conclusions can be made at this time as to either the limits of the capacity of wild geese to utilize feather keratin as a mode of mineral excretion or the nutritional significance of excretion rates via the feather follicle. The actual mode and sequence of events responsible for mineral incorporation into the feather do not appear to be particularly relevant to the initial practical objective of the study, i.e., to be able to determine the origin or birthplace of individual birds or populations in autumn and winter. This objective is particularly significant to management of lesser snow and blue goose populations, most of which are indistinguishable morphologically, although the birds breed in widely separated colonies.

More feather elements differ significantly between these two populations than is the case for similar comparisons between some other populations we have studied. However, the technique is useful if the population in question can be differentiated from all others by only one element. Obviously a population distinctive in two or more elements is more readily identified, and a spectrum of 12 elements, theoretically, should permit a great number of distinctive mineral "profiles" to be distinguished among all populations. However, variability within most populations considerably limits the actual number of distinctive permutations likely to occur.

Banding has made enormous contributions to our understanding of the distribution and seasonal movements of birds, but the shortcomings of this technique are manifest—chiefly, the fact that bandings in any one year are parochial in representation and the application of band recovery data often involves tenuous statistical assumptions and corrections. It is hoped that the technique and findings reported here will open a new era of more refined identification and management of waterfowl populations (Fig. 2). Although the method described involves complex and expensive instrumentation, our data for color of the feather ash (Jones and Hanson, unpublished) of the various populations of lesser snow and blue geese indicate that some are also "color coded" to their birthplace or breeding area. To identify these it is only necessary to wash the clipped vanes of the primary feathers, burn them to ash in a muffle furnace, and carefully note the color (Munsell or some other notation system) to establish the birthplace.

Studies of trace minerals occurring in natural populations, whether in keratin structures or body structures, have considerable potential. For example, the hypothesis has been advanced that soil calcium is a limiting factor in the southward distribution of the ring-necked pheasant (*Phasianus colchicus*) in the United States (Leopold 1931:125). Because the amount of a mineral in feathers appears to be an expression of the extent to which it occurs in excess of metabolic needs in the nutrient chain, feather calcium or its ratio to some other element or elements may provide new insight into the question of pheasant range limitations.

Feather analysis may be useful in a wide range of nutritional studies because results can be obtained without sacrificing the experimental individuals. Prior to the present studies, Dr. Harold M. Scott of the College of Agriculture, University of Illinois, and the senior author held three groups of Canada geese on experimental rations that differed in only two respects—in methionine content and including a supplement of $MgSO_4$—from the diet containing the standard mineral mix used at the College in experimental feeding

Fig. 2.—Lesser snow and blue geese in a cornfield on the Squaw Creek National Wildlife Refuge in northwest Missouri. The changing habits of these geese and increasing kills made by hunters at points along the migration routes emphasize the need for better information about the origins of such populations.

of poultry. Fortunately the primary feathers from these geese, which were sacrificed, were saved, partly because it was noted at the time that they had not developed normally, being more curved and "foreshortened" than feathers of normal wild birds. Therefore it was of interest to note that the feathers of all three experimental groups of geese revealed much lower contents of most of the minerals we analyzed for than were found in any wild populations thus far studied. These findings suggest that an ultimate of economy in the design of poultry rations may have been approached, but the data also raise the question of whether or not the highly enriched diets of wild birds could play a role in their tremendous vigor and recuperative powers.

To answer the many questions which this preliminary study raises, all factors in the nutrient chain in the ecosystem will have to be studied. For a number of localities in the Arctic we have analyzed samples of the soil, plant food, feathers, and feces. These analyses are providing insights unlikely to be obtained by studies of caged birds alone.

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HTLIGHTING:

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ALD F. LABISKY

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Fig. 1.—Nightlighting is currently the most commonly used technique for capturing pheasants throughout the United States. This cock pheasant eluded capture on this trapping attempt, but was subsequently pursued and captured.

NIGHTLIGHTING: Its Use in Capturing Pheasants, Prairie Chickens, Bobwhites, and Cottontails

Ronald F. Labisky

THE IDEA OF USING BRIGHT LIGHTS at night to blind animals temporarily so that they may be captured is certainly not new. Prehistoric man probably used the light from burning torches in capturing wild animals. Nightlighting in modern game management was first demonstrated by workers in South Dakota in the 1920's. Oscar Johnson (Leopold 1931:118) reported that about 22,000 pheasants, *Phasianus colchicus,* were captured in South Dakota during the winters of 1926–1927 and 1929–1930 by "shining" roosting birds with automobile headlights. However, nightlighting did not become a commonly used technique in wildlife biology until research studies, which proliferated rapidly after the mid-1940's, necessitated the capture of large numbers of wild birds and mammals.

Nightlighting has been used most commonly to capture pheasants, as is indicated by numerous published accounts, including reports from Idaho (Anonymous 1952), South Dakota (Smith 1954), Nebraska (Anonymous 1955), California (Hart *et al.* 1956:137), Illinois (Labisky 1959), North Dakota (Oldenburg 1961), Indiana (Ginn 1964), and Iowa (Lyon 1965:51). The pheasant lends itself well to capture by nightlighting because it principally inhabits agricultural regions and thus roosts in cropland terrain that is traversable by vehicles equipped for nightlighting (Fig. 1). Nightlighting has been a particularly valuable technique for capturing large numbers of pheasants in states such as Illinois, where bait trapping of pheasants in winter is precluded by an abundant, and usually available supply of waste grains. Vehicle-borne nightlighting rigs have also been used to capture cottontails, *Sylvilagus floridanus,* and nongame birds (Labisky 1959), skunks, *Mephitis mephitis* (Andrews 1963), and bobwhites, *Colinus virginianus* (Bartholomew 1967).

Nightlighting equipment installed on various watercraft has been effectively used to capture waterfowl and marsh birds (Leitch 1958; Lindmeier & Jessen 1961; and Cummings & Hewitt 1964). Battery-powered headlamps or hand-held lights have been used to capture large numbers of woodcocks, *Philohela minor* (Rieffenberger & Kletzly 1967), and a variety of gulls and shorebirds (Taapken & Mooyman 1961). Also, generator-equipped, backpack nightlighting units have been proven effective for capturing birds and mammals in environments, either aquatic or upland, where other methods of trapping were either inconvenient or unsuccessful (Drewien *et al.* 1967).

My previous article on nightlighting (Labisky 1959) was concerned primarily with the application of the technique to capturing pheasants. The purpose of this paper is to list improvements in equipment (and operational design) used in outfitting vehicles for nightlighting and to describe techniques for capturing bobwhites; prairie chickens, *Tympanuchus cupido;* cottontails; and pheasants.

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EQUIPMENT

The basic equipment (Fig. 2) for outfitting a vehicle for nightlighting consisted of a floodlight cluster, a power source to operate the floodlights, and a spotlight. A vehicle equipped with 4-wheel drive is recommended, although not essential, for nightlighting.

The floodlights have been operated from 110-volt a-c or 12-volt d-c power sources. The power supply for d-c systems was rigged by replacing the vehicle's factory-installed alternator with a high-amperage alternator. However, d-c systems provided less illumination than a-c systems because the available d-c lamps had lower candlepower ratings than a-c lamps. Consequently, under ordinary situations, a-c systems were favored for nightlighting work, and thus are given primary consideration in this report.

The a-c floodlight cluster consisted of five 150-watt PAR/FL projector floodlamps. These were held most satisfactorily by Killark Model SLH lampholders mounted in a Killark Model SY wiring trough. The trough was mounted at the top of a modified tripod

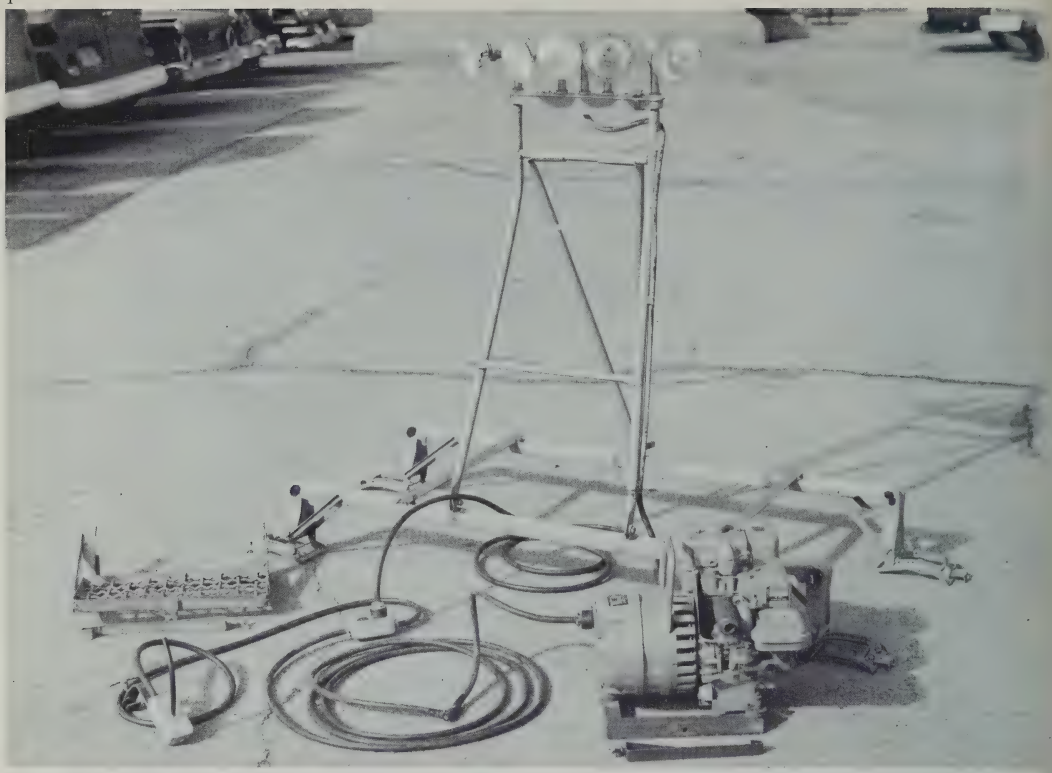

Fig. 2.—The basic equipment for nightlighting, excluding the hand-held spotlight, consists of a gasoline generator (with clamp), floodlight cluster, and wiring system. The toggle switch for the floodlights appears in the left foreground; the netter's platform (with clamp) is at left center; and the in-line fuse is visible in the center area of the major coil of cable. This identical set of equipment is used on the different vehicles shown in Fig. 1 and Fig. 4.

(Fig. 2) made from 3- or 4-foot sections of 1-inch metal conduit. The tripod, depending on its design, was fastened to a sturdy, metal cartop carrier either with bolts or with clevis-type hinges. The clevis hinges permitted the floodlight cluster to be easily folded down for highway traveling or for avoiding low-hanging obstacles.

The lampholders were individually adjustable so that the area illuminated by the lamps could be controlled. The lamps were tilted downward when cruising in cover that absorbed light (e.g., heavy green vegetation) and lifted slightly in cover that reflected light (e.g., snow). The floodlights ordinarily were adjusted to yield a semicircle of adequate light extending about 10 yards on either side of the vehicle and 30 yards forward; beyond these distances the light was diffuse.

Electrical power for the a-c floodlamps was supplied by a 110–120-volt, 1,250-watt, gasoline-powered generator (Montgomery Ward model), which could be purchased with or without an electric starting motor. The 1,250-watt capacity of the generator was sufficient to supply the starting electrical surge for the five, 150-watt floodlamps, which subsequently drew only 750 watts. This generator was small enough to be mounted, by bolting it to the frame, under the hood of some vehicles. Usually, however, it was mounted on a platform, or angle iron frame, which could be readily clamped to the rear bumper of a vehicle (Fig. 3).

The power cable for the electrical system consisted of about 15 feet of neoprene-covered motor cord with 14-gauge, 600-volt wires. A polarized male plug to fit into the receptacle on the generator was attached to one end of the cable. About 10 feet from the generator an outlet receptacle, inserted in a handy box, was installed in the line (Fig. 2). A 20-ampere cartridge-type fuse (automotive) was installed in this line between the generator and outlet receptacle. One wire of the power cable was extended through the handy box for about 5 or 6 feet to a single pole, single throw, 25-

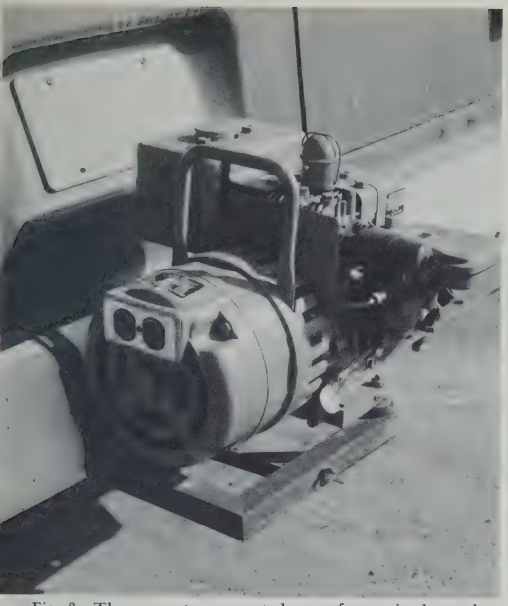

Fig. 3.—The generator, mounted on a frame, is clamped to the rear bumper of the vehicle with two steel-strap hanger brackets that hook over the top edge of the bumper. The curled end of the center clamp is hooked over the bottom edge of the bumper, and the threaded end of this clamp, which is inserted through a drilled hole in the rear piece of the mounting frame, is secured with a wing nut.

ampere, 110-volt toggle switch, which was installed in a second handy box equipped with a switch-type cover plate. The return wire from the switch to the receptacle was attached to the second, or free, terminal of the receptacle to complete the circuit. A second length of cable, about 8 feet, leading from the wiring trough for the floodlamps and terminating in a male plug to be inserted into the outlet receptacle, was used to complete the circuit to the lamps. The toggle switch controlled the floodlights. The handy box with toggle switch was outfitted with clamps so that it could be attached either to the center of the dash or on the roof of the vehicle above the driver's right shoulder. The switch was fitted with a 6-inch extension of semiflexible rubber tubing so that it could be located easily and turned on or off with a flick of the hand.

The hand-held spotlight used in this work was a Unity Model S6, 100,000 candle power, 12-volt automobile searchlight. It was sometimes operated from the vehicle's cigarette lighter socket. Usually, however, a short electrical cable, terminating in a female receptacle, was run from the posts of the vehicle's 12-volt battery, through the firewall, to the interior of the vehicle. The spotlight cable was then fitted with a suitable male plug. The latter system offered the most trouble-free performance.

The a-c lighting system with a bumper-mounted generator has the advantage of being interchangeable among different vehicles, particularly those of similar make (Fig. 1 and 4). All equipment can be rigged and readied for operation by two men within 10 minutes.

Fig. 4.—The crew of this nightlighting rig is cruising a grain-stubble field to locate roosting pheasants.

The net used to capture gallinaceous birds and cottontails had a 10-foot handle of 1-inch, thin-walled conduit, and a 30-inch hoop (diameter) of rolled ¾-inch, thin-walled conduit. The bag of the net was constructed of 1-inch heavy cord mesh and had a depth of about 15 inches. Nets with handles of lightweight materials or with bags of less than 1-inch mesh were ineffective because they could not be quickly forced down to the ground in heavy vegetation. Bags of fine cord, particularly those with mesh sizes larger than 1 inch, were unsatisfactory because netted birds often became entagled in the mesh and suffered wing abrasions.

To give the driver good visibility, the netter rode on the right fender of the vehicle. He was provided a detachable bumper platform on which to place his feet (Fig. 2). A safety rope, which the netter could grasp in his left hand, was attached across the hood of the vehicle. The platform and safety rope were essential to the safety and performance of the netter.

A two-man crew was adequate for the effective operation of this nightlighting rig. One man drove the vehicle, controlled the floodlights, and operated the spotlight, which he held out of the window of the vehicle. The other man netted the animals.

TECHNIQUES AND EFFICIENCY OF CAPTURE

Pheasants

Pheasants were located at night by cruising, with the floodlights in operation, through fields of relatively flat terrain that offered roosting cover, such as hayfields, small-grain stubble fields, and pastures (Fig. 4). Such cruising was done at about 5 mph. When a roosting pheasant was observed in the arc of the floodlights, the driver simultaneously switched on the hand-held spotlight, pinpointed the bird with the spotlight beam, and switched off the overhead floodlights. He then drove toward the bird, keeping it centered in the spotlight beam until the netter could leap from the vehicle and make his netting attempt (Fig. 5). Inasmuch as the spotlight was held in the driver's left hand, the vehicle had to be maintained to the right, or right rear, of the bird, which normally moved away from the source of light and noise. Consequently, the most effective vehicle maneuver in nightlighting was a counterclockwise circling action.

To net a pheasant, or other bird, the netter approached only from the rear or from the spotlighted, or "blinded," side of the quarry. In the capture attempt for pheasants, the netter usually made a headlong dive from a running approach. He placed the net swiftly over the bird by a forceful, forward thrust in such a manner that the hoop passed only a few inches over the bird; the hoop was kept essentially parallel to the ground at all times. This method of net placement allowed the netter to adjust for sudden, last-instant reactions of the bird, thereby increasing trapping efficiency and lessening the chances of injuring the bird. The action of the driver and the netter had to be closely coordinated to achieve a high degree of efficiency in capturing pheasants.

Most pheasants were captured at distances of 25–50 feet from the vehicle. Long chases, away from the vehicle, of elusive birds by a netter on foot were usually unsuccessful; they not only tired the netter but also wasted time and flushed birds that otherwise might have been captured. Although some birds were taken at or within a few feet of their roosting sites (Fig. 5), most birds either ran or flushed from their sites when they were disturbed (Fig. 1). The latter pheasants were spotlighted and pursued until they were captured or reached an inaccessible area. When a pheasant flushed, it could be "knocked down" at distances up to 150 yards by the spotlight beam if the bird was oriented in flight so that the light reached one of its eyes, temporarily blinding the bird. When a group of pheasants was flushed at one time, several birds could often be "knocked down" with the spotlight before they flew very far. In such cases the driver mentally noted the positions of the downed birds and subsequently pursued them one by one.

When pursuing running or flying pheasants, speeds of from 15 to 20 mph were often necessary to put the vehicle (and netter) in position to attempt capture; such chases often covered distances of several hundred yards. Under these circumstances, the driver had to be well acquainted with the terrain because his only light source was the spotlight beam which was directed at the fleeing bird.

Adult, or essentially full grown, pheasants were captured more easily when they were found roosting singly or in groups of two or three than when they were found in larger groups. If a single member of a large group flushed, several of the other pheasants in the group usually flushed also, some of which often flew into nearby fields that were inaccessible to the nightlighting rig. Many of the pheasants that flushed flew only short distances before alighting and were available for subsequent capture attempts. Young pheasants, still in broods, were very easily captured.

Pheasants were usually easier to capture after they had been roosting for a few hours than they were shortly after sunset or immediately before sunrise. Repeated nightlighting within the same field caused pheasants to become skittish, which made them increasingly difficult to trap, but did not markedly alter their nighttime use of the field.

Although there were never nights during which a worthwhile number of pheasants could not be captured by nightlighting, nighttime conditions influenced the susceptibility of birds to capture. Strong wind

Fig. 5.—In this capture effort the relative positions of vehicle, netter, and pheasant about to be captured at his roosting site are typical.

(15 mph or more) caused roosting pheasants, particularly those in large flocks, to flush wildly. Wind also caused vegetation to wave, which made it difficult for the observers to locate and follow pheasants that ran from their roosting sites.

Although fog or rain often caused pheasants to "hold tight" to their roosting sites, these same weather conditions usually hindered the trapping operation more than they aided it because of low visibility, reduced effectiveness of lights, and, in the case of rain, soft fields. Pheasants were most susceptible to capture when the vegetation was wet with dew or covered with frost. Cold temperatures (−10° to 10°F.), particularly when the ground was covered by snow, caused roosting pheasants to be flighty. Under the latter conditions in Illinois, pheasants often roosted in corn stubble (rather than in small-grain stubble or hay), which made their capture by nightlighting very arduous because it is difficult to maneuver the vehicle in row-crop fields. Pheasants were more susceptible to capture by nightlighting on moderately cold, cloudy nights following rain in autumn, and on relatively warm nights following a marked cold spell in winter. In late winter and spring, soft fields, which prevented vehicle access, hampered the capture of pheasants more than any other factor.

Pheasants were skittish and difficult to capture on bright moonlit nights, particularly when the vegetation was dry or covered by snow. When the vegetation was dew-laden or frosty, moonlight seemed to have little effect on the flightiness of pheasants.

Nearly half of all pheasants initially observed during nightlighting operations in autumn (prehunting season) were captured, whereas only about a third of those located in winter (posthunting season) were captured (Table 1). Although total pheasant numbers were less after each hunting season than before, the number of roosting pheasants per unit of trappable cover was greater after the hunting season than before. Fall plowing of small-grain stubble and hay fields severely reduced the amount of cover that had been used by roosting pheasants in autumn, and by the beginning of winter the birds were concentrated in the fields that offered vegetation suitable for roosting. Even when large blocks of roosting cover were available, pheasants often roosted in large flocks, sometimes as many as 200 birds, on winter nights. In general, the percentage of pheasants captured varied inversely with the number of pheasants that were flushed per unit of cover searched.

The time required to capture a pheasant averaged 5.5 minutes in autumn and 6.8 minutes in winter during the 6 years, 1956–1962 (Table 1). In autumn the capture time per bird decreased as population abun-

TABLE 1.—Statistics on the efficiency of capturing pheasants by nightlighting during prehunting season (October and early November) and posthunting season (principally January) periods on the intensively farmed, 23,200-acre Sibley Area in Ford and McLean counties of east-central Illinois, 1956–1962.

Capture Period and Year	Pheasant Density (Birds per Square Mile)	Number of Pheasants Captured	Capture: Flush Ratio* (Percentage Captured)	Average Capture Time (Minutes per Bird)
Autumn or Prehunt				
1956	150	267	37	7.0
1957	145	220	47	7.4
1958	295	354	50	4.8
1959	210	183	53	5.4
1960	285	181	40	5.3
1961	370	369	54	4.1
Total or Mean		*1,574*	*46*	*5.5*
Winter or Posthunt				
1957	60	189	36	8.5
1958	110	127	42	10.0
1959	95	177	16	5.0
1960	110	182	40	5.4
1961	150	187	38	6.0
1962	(160) †	260	37	No data
Total or Mean		*1,122*	*31*	*6.8‡*

*Efforts were made to include only the initial flush of pheasants; repeat flushes were ignored because they were a product of capture attempts.
†Estimate.
‡Excludes 1962.

dance increased. In winter there was little relationship between capture time and population abundance because the birds were usually concentrated in fields offering roosting cover.

Mortality attributable to the nightlighting operation totalled 1.7 percent of 2,696 pheasants captured and processed (weighed, measured, and marked). The majority of this mortality occurred during the time that the pheasants were held in burlap bags prior to processing. Such losses were mitigated if only one or two pheasants were placed in each burlap bag, if cocks and hens were held separately, if the pheasants were held no longer than 1 hour prior to processing, and if the bags containing the captured birds were kept outdoors.

Prairie Chickens

Efforts to capture prairie chickens by nightlighting were restricted to a single colony of birds located on a 10,000-acre tract of agricultural land in south-central Illinois. This colony numbered about 300, 200, and 150 prairie chickens in the autumns of 1962, 1963, and 1964, respectively. In autumn these birds were found roosting, usually in small groups, in as many as 20 different fields of small-grain stubble or tame hay.

Prairie chickens were much less susceptible to capture by nightlighting than were pheasants. Only 57, or about 17 percent, of 327 prairie chickens that were initially observed (repeat flushes not included) while nightlighting during the late summer and early fall periods of 1962–1964 were captured (Fig. 6). The capture efficiency was about 19 percent in August (17 of 88 birds), nearly 28 percent in September (28 of 101 birds), and only about 9 percent in October (12 of 138 birds). Young birds were more easily captured than adults in August and early September, but had gained the wariness of adults by October.

The techniques for nightlighting prairie chickens were essentially the same as those used in capturing pheasants. However, the entire tempo of the operation, after observation of the bird, had to be accelerated to effect capture. Even with experienced nightlighting personnel, the capture of prairie chickens was not assured.

Prairie chickens were almost impossible to capture by nightlighting on clear and/or moonlit nights. Under these conditions the spotlight was completely ineffective in "knocking down" prairie chickens that flushed. The flushed birds usually flew out of sight before alighting, which prevented subsequent capture attempts.

Cloudy, cool, and damp nights in early autumn were the best for capturing prairie chickens. To illustrate, on one night in mid-September, 1963, 21 (55 percent) of 38 prairie chickens that were flushed were captured —9 were adults and 12 were juveniles. This particular night was characterized by the arrival of a low-pressure weather front. It was very dark, due to a heavy cloud layer; mildly wet, due to a persistent mist; and cool (about 45° F.). The success in capturing prairie chickens on this night was convincing evidence that they could be effectively captured by nightlighting under proper nighttime conditions.

Fig. 6.—This prairie chicken, captured by nightlighting, was marked for subsequent identification with a plastic backtag prior to its release. (Most of the pheasants and bobwhites captured by nightlighting were also marked with backtags to facilitate behavioral and ecological studies.)

Bobwhites

Bobwhites were susceptible to capture by nightlighting, but the problems involved in capturing them were much different from those encountered in capturing pheasants or prairie chickens. Locating coveys of roosting bobwhites was perhaps the most time-consuming part of the operation. This problem was most acute in areas where bobwhite densities were low or where uneven topography, often characteristic of good bobwhite range in Illinois, made it impossible to use a vehicle. Beforehand knowledge of covey ranges lessened the cruising time expended in locating roosting coveys at night. Bartholomew (1967:3) tried to expedite the problem of locating coveys at night by working pointing dogs ahead of the lights, but concluded that the systematic search of fields with the nightlighting rig was still the best method for locating roosting bobwhites.

Usually the first indication of the presence of a roosting covey was when the birds flushed in the light ahead of, and usually close to, the vehicle. If a covey was sighted in a roosting rosette and could be pinpointed in the spotlight beam, all or most of the covey members could be captured in a single netting attempt. When a covey flushed, individuals scattered in all directions, but usually alighted within 5–75 yards of the flush point. Consequently, the floodlights were often left on when a covey flushed so that both driver and netter could observe the flightlines and flush distances of as many of the birds as possible. In these instances the spotlight was still used to "knock down" individual birds, particularly those that flew beyond the area illuminated by the floodlights.

The techniques used for trapping bobwhites depended on the type of habitat. When vegetative cover was relatively light, as in fields of small-grain stubble, birds from a flushed covey usually walked or ran after alighting. It was not unusual for a covey to "pop" into the air, alight immediately, and then run, often stay-

ing together in a loose unit. Capture efficiency was high under these circumstances because the fleeing birds could be easily observed on the ground. Inasmuch as scattered bobwhites were not particularly prone to flush, the birds were relatively easy to net (Fig. 7). A skilled netter could sometimes maneuver so as to make multiple catches, usually two or three birds.

Bobwhites were more difficult to capture when roosting in heavy vegetative cover. After the covey was flushed, individuals usually settled into the cover and remained sedentary. Most of these birds had to be relocated by slow, methodical cruising, and the best method was to cruise in a spiral pattern, moving outward from the flush site. To capture a bobwhite in this heavy cover, it was necessary to see the bird on the ground, detect it by its movement (by sight or sound) in the vegetation, or reflush it. When a bird was either seen or detected by its movement, netting was usually done in the illumination of the floodlights. Reflushed bobwhites were spotlighted and pursued in the normal way, and the netter usually trapped the bird by thrusting the net over the spotlighted site where it alighted. When nightlighting in heavy vegetation, many of the captured bobwhites were netted "blind"—the netter trapped the bird by placing his net over a spot of vegetation where the spotlight operator had detected movement and directed the light beam.

Wind was the weather condition that most hampered the capture of bobwhites by nightlighting; it set the vegetation in motion, making it difficult or impossible to detect the birds' movements. Quiet, dark, cloudy nights with heavy dew, light rain, or frost were favored for nightlighting bobwhites.

About half of all bobwhites flushed in farmland habitats, but only a third of those flushed in nonfarmland habitats, were captured by nightlighting in autumn (Table 2). The capture efficiency in the two broad habitat types was influenced by two factors. First, nightlighting for bobwhites on farmland was done principally in fields of small-grain stubble, where often the vegetation was either short (sometimes mowed) or light to moderate in terms of stem density. In such cover bobwhites were observable and, thus, easily trapped. On nonfarmland, nightlighting usually had to be conducted in fields of undisturbed grasses and weeds that were interspersed with deciduous woods. Scattered bobwhites were difficult to relocate

Fig. 7.—Here an undetected bobwhite from a previously flushed covey was reflushed as the netter approached another spotlighted covey member (on ground) from the outer fringe of the area illuminated by the floodlights. The driver instantaneously centered the flushing bobwhite in the spotlight beam so as to quickly "knock" him down.

TABLE 2.—Statistics on the efficiency of capturing bobwhites by nightlighting during autumn (prehunt) on farmland habitats and on nonfarmland habitats in south-central Illinois, 1963–1967.

Type of Habitat and Year	Number of Coveys Flushed	Number of Bobwhites in Coveys	Number of Bobwhites Captured	Percentage of Bobwhites Captured
Farmland*				
1963	15	147	91	62
1964	8	102	36	35
Total or Mean	*23*	*249*	*127*	*51*
Nonfarmland†				
1963‡	17	227	101	44
1964‡	17	196	74	38
1965‡	9	110	41	37
1966	8	109	21	19
1967	11	195	45	23
Total or Mean	*62*	*837*	*282*	*34*

*Bobwhite densities averaged about 1 covey per square mile.
†Bobwhite densities averaged about 12 coveys per square mile.
‡Two nightlighting rigs, working as a dual unit, were used in trapping in 1963 and at least part of the time in 1964 and 1965.

in this dense vegetation. Second, on nonfarmland many flushed bobwhites flew into nearby woods or rough terrain where they could not be pursued. This problem was not often encountered on the comparatively flat, farmland terrain.

The use of two nightlighting rigs usually improved the capture efficiency for bobwhites (Table 2), particularly in heavy vegetation or rough terrain, because it was possible to note where more of the birds from a covey alighted after the initial flush. Also, one rig and crew could often intercept and quickly capture individuals that were flushed by the other rig.

The time required to capture a bobwhite is unpredictable. Usually attempts to capture birds from an average-sized covey reached the point of diminishing returns within 30–45 minutes in light cover and 60–90 minutes in heavy cover. On one occasion, where the birds were roosting in clipped grain stubble, we captured 16 birds from a covey of 18 in less than 30 minutes. On the other hand, we captured only 4 of 22 bobwhites during a 2-hour period following a covey flush from a field of tall grasses and weeds.

Although we did not engage specifically in nightlighting for bobwhites during the winter, those bobwhites flushed while trapping pheasants were susceptible to capture. They were exceptionally vulnerable when snow covered the ground because they were readily visible against the white background.

Mortality of bobwhites attributable to the nightlighting operations averaged less than 1 percent. Roosting behavior was not seriously affected by nightlighting activities, as nightlighted coveys could be relocated at, or near, the same sites on subsequent nights.

Cottontails

Capturing cottontails (Fig. 8) by nightlighting was a difficult task. We have, however, captured more than 300 rabbits by nightlighting during the past decade. Nightlighting, by itself, was not a feasible technique for capturing large numbers of cottontails for population studies. However, it did prove to be an adequate and convenient technique for capturing live cottontails for laboratory studies or for stocking enclosures with animals for subsequent biological investigations.

Nightlighting cottontails was a hard and fast operation. At night the cottontail was strikingly "an animal of the edge." Generally, it foraged only short distances, usually less than 50 yards, into fields, or, more accurately, away from its escape cover. And as soon as the cottontail was disturbed, it streaked toward its escape cover. Consequently, the first and most important step in attempting to capture a rabbit was to

Fig. 8.—Although success in capturing cottontails by nightlighting on any given night is unpredictable, an experienced crew can usually capture a few rabbits on almost any night.

maneuver the vehicle between the rabbit and its escape cover. To accomplish this, spurts of speed up to 35 mph were often necessary, and thus only fields with smooth terrain could be safely and effectively nightlighted. Because the "target" rabbit had to be kept in the spotlight beam at all times, it was imperative that nightlighting be done in fields in which the vegetation permitted the rabbit to be seen at all times; when the animal was lost from view, it usually escaped. If a rabbit could be cut off from escape cover, it often paused momentarily; at this moment the rabbit was potentially most vulnerable to capture. To effect capture at this precise time, the driver had to have the vehicle in such a position that the netter could literally pounce, directly from the vehicle, upon the rabbit with the net.

An experienced nightlighting crew can, on the average, expect to capture about one of every five rabbits flushed. On different nights in autumn, we have captured as many as 13 of 36 cottontails (36 percent) in 3 hours of nightlighting and as few as 3 of 51 (6 percent) in 7 hours.

Subadult cottontails were more susceptible to capture by nightlighting than were full grown rabbits. However, the nighttime behavior of cottontails, and thus their trappability, was quite unpredictable at any time. Cottontails were most skittish on very cold, moonlight nights when snow covered the ground and were most susceptible to capture on dark, cloudy nights when the vegetation (or ground) was wet. As a rule, cottontails held best on cold, rainy nights in autumn, on cool nights following a thaw or snow in winter, on warm, humid nights in spring, and on cool, dewy nights in summer.

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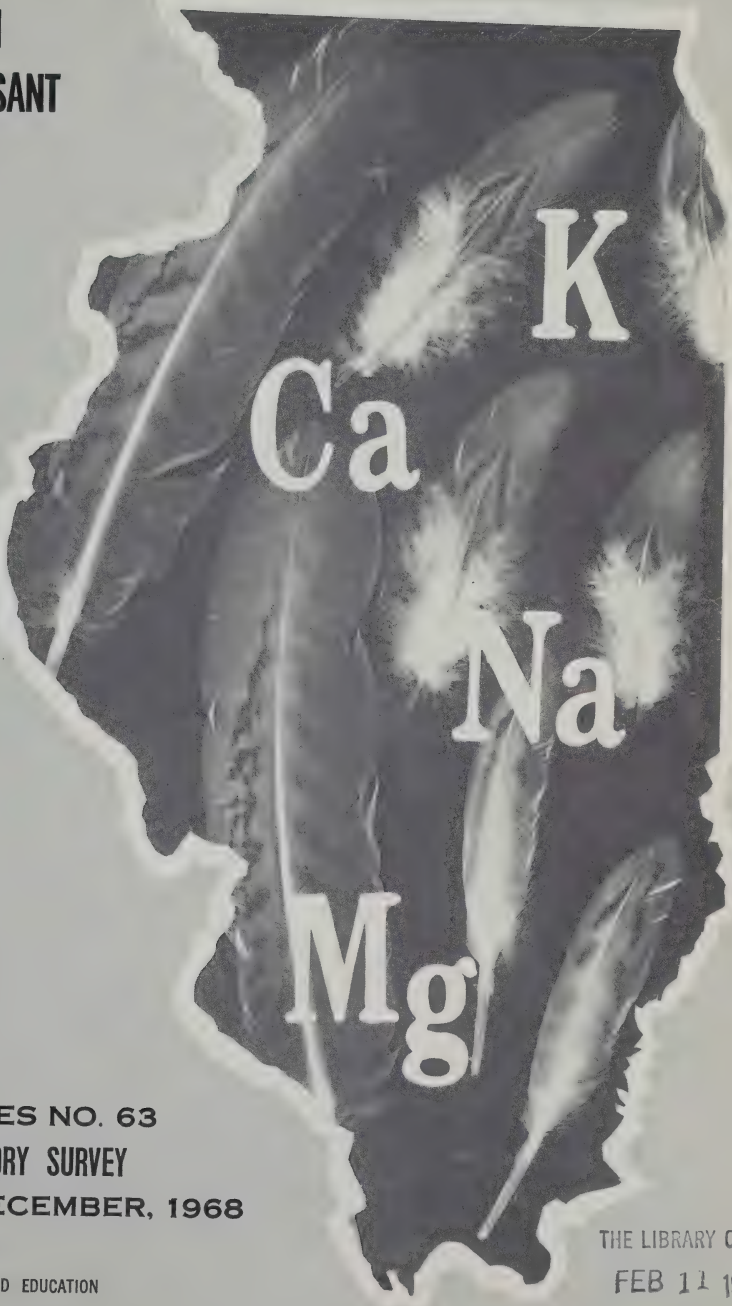
SELECTED MINERALS IN SOILS, PLANTS, AND PHEASANTS:

AN ECOSYSTEM APPROACH TO UNDERSTANDING PHEASANT DISTRIBUTION IN ILLINOIS

Robert L. Jones
Donald F. Labisky
William L. Anderson



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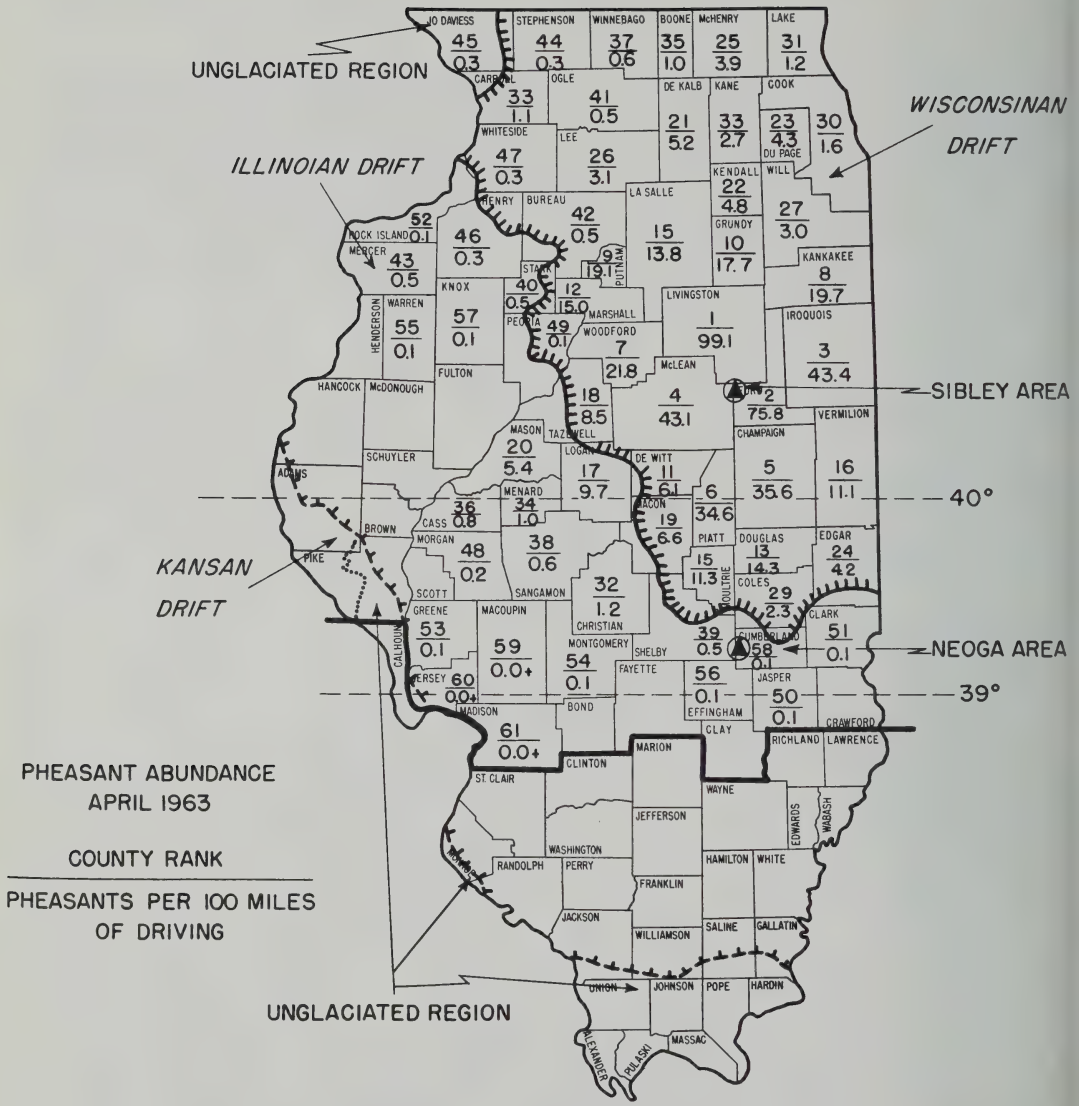

Fig. 1.—Distribution and abundance of pheasants in Illinois in relation to the most recent (Wisconsinan) and older glacial drift The solid and broken lines with projections designate the terminal boundaries of the Wisconsinan and Illinoian ice sheets. A sma region of the exposed Kansan drift is located in southwest-central Illinois. The pheasant abundance statistics were derived from a 196 rural mail carrier census (after Labisky & Anderson 1965:129–130); rank was assigned only to the 61 counties from which pheasan were reported. The 28 southernmost counties, below the heavy black line, are classed as nonpheasant range (Greeley *et al.* 1962:14

Selected Minerals in Soils, Plants, and Pheasants: An Ecosystem Approach to Understanding Pheasant Distribution in Illinois

Robert L. Jones, Ronald F. Labisky, and William L. Anderson

In the eastern half of the United States the exotic pheasant (*Phasianus colchicus*) occupies a band of contiguous range, except along the Mississippi River, from Iowa and southern Minnesota across southeastern Wisconsin, northeastern and east-central Illinois, northern Indiana, southern Michigan, and into Ohio and Pennsylvania. Yet, despite repeated introductions following its initial establishment in the eastern United States during the early 1900's, the pheasant has never established self-maintaining populations south of the 39th parallel. Factors potentially responsible for limiting the southward expansion of pheasant range in Illinois (Fig. 1) and elsewhere in the eastern United States, such as land use, climate, and a calcium deficiency, have been the subject of considerable research —and of conflicting findings (Labisky *et al.* 1964).

A deficiency of soil minerals, and particularly of calcium, has long been considered one of the major factors affecting pheasant distribution. Leopold (1931:125) pointed out that pheasants were confined mainly to range within the boundary of the most recent, or Wisconsinan, glaciation. He suggested that some plant or substance, such as lime (calcium carbonate) or gravel, present in geologically young soils was necessary for the establishment and maintenance of pheasant populations.

Years later Dale (1954:320) revived interest in the "calcium hypothesis" by reporting that pheasant abundance in the eastern half of the United States was apparently correlated with the availability of calcium in soils. Dale (1955), Dale and DeWitt (1958), and Greeley (1962) then studied the calcium requirements of pen-reared pheasants to establish minimum amounts of calcium necessary to maintain physiological balance, particularly during the reproductive period when demands for calcium are high.

At this point it was apparent that the organic items eaten by wild pheasants did not supply sufficient calcium to meet their physiological needs, particularly for reproduction. The logical supplementary source of calcium was calcium-bearing grit. McCann (1961: 189–190) reported that wild pheasants in Minnesota were most abundant on soils that contained grit that was relatively rich in calcium and poor in magnesium. Subsequent reports by Harper (1963, 1964) and Korschgen (1964) described the intake of calcium from grit and foods by wild pheasants in the midwestern United States. The finding that the wild pheasant hen apparently has the ability to select calcium-rich grit in preference to calcium-poor or noncalcareous grit constituted an important contribution toward understanding how the pheasant fulfills its requirements for this mineral (Sadler 1961; Harper 1964; Harper & Labisky 1964; Korschgen 1964; Kopischke & Nelson 1966; and Kopischke 1966).

In Illinois Harper and Labisky (1964) investigated the possibility that a deficiency of calcium was a factor limiting the southward spread of pheasants. They compared the availability of calcium and its ingestion and physiological use by wild pheasants on two areas, Neoga and Sibley, located on the geographically older Illinoian-age drift and on the comparatively younger Wisconsinan-age drift, respectively (Fig. 1). Harper and Labisky (1964:729–730) concluded that both the availability of calcium on the older drift and its ingestion by pheasants were adequate to establish self-maintaining pheasant populations. However, as Labisky *et al.* (1964:12) later pointed out, this conclusion does not contradict the possibility that a deficiency of some other mineral or of some vitamin might prevent the establishment of self-maintaining populations of pheasants on pre-Wisconsinan drift.

The objectives of the research reported here were 1) to determine if the concentrations of four essential elements—sodium, potassium, calcium, and magnesium —in the primary feathers of pheasants from a high-density population on Wisconsinan drift differed from those of pheasants from a low-density population on pre-Wisconsinan drift, and 2) to learn if the relative concentrations of minerals in feathers reflected the levels of these elements in the nutrient chain (i.e., from soil to plant to pheasant).

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STUDY AREAS

The two areas from which soils, plant seeds, and pheasants were collected were the two areas—Neoga and Sibley—studied by Harper and Labisky (1964). The Sibley Area (23,200 acres), which supports thriving populations of wild pheasants, is located on Wisconsinan drift (Fig. 1). In contrast, the Neoga Area (10,240 acres), which lies in the southern fringe of the contiguous range of the pheasant in Illinois, is found on the geologically older Illinoian drift. The low-level pheasant population on the Neoga Area originated from releases of various strains of propagated pheasants and of transplanted wild pheasants (Anderson 1964). Both of these areas are intensively farmed; corn and soybeans are the major crops.

These two areas differ markedly in geomorphology, age, and nature of soils. The Sibley Area lies within that region of rolling topography formed by the Normal and Cropsey morainic system; about two-thirds of it lies on a gently undulating morainic ridge and the remainder on a broad, flat outwash apron. The till is calcareous; the Cropsey moraine, in La Salle County, has a mean calcium carbonate content of 23 percent (Jones *et al.* 1966:366). The soils, which reflect the fine-textured nature of the glacial till, are silt loams or silty clay loams. The major soil series found on the Sibley Area are Elliott and Saybrook, both classified as Brunizem or Prairie soils, and Drummer, classified as a Humic-Glei soil. Elliott and Drummer occur on the moraine and Saybrook on the outwash apron. All of these soils are near neutral in pH in their surface horizons and have high natural productivity; most of the soils are tile drained. The age of the soils of the Sibley Area is probably about 16,000 years. However, a small amount of younger loess is incorporated in the surface horizons (Jones & Beavers 1963:439–440).

The Neoga Area lies immediately south of the outwash apron bordering the Shelbyville moraine, the terminal moraine of Wisconsinan glaciation (Fig. 1). Topographic relief is slight at Neoga. The soils of the study area, being of pre-Wisconsinan origin, have had a longer and more complicated history of development than those of the Sibley Area. The till is calcareous only at depths greater than 3.4 meters. Two predominant soil series, Cisne and Ebert, are found at Neoga. Cisne, a Planosol, is characterized by a shallow clay layer that impedes drainage. Ebert, an intergrade soil having properties between a Planosol and Humic-Glei soil, is more poorly drained than Cisne. Both soils are moderately acid; the pH in the surface horizons ranges from 5.3 to 6.0 in Cisne soils and from 5.6 to 6.5 in Ebert soils. These soils developed in 1.2 meters of loess (Fehrenbacher *et al.* 1965:568) overlying Illinoian till that has an ancient soil or paleosol in it. This paleosol is quite impermeable and restricts internal drainage. Thus, these soils, which have low natural productivity, are mostly surface drained. The Neoga soils may be 100,000 or more years old.

TECHNIQUES

Sample Collections

Samples of seeds commonly consumed by pheasants —corn (*Zea mays*) and Chinese foxtail (*Setaria faberii*)—and soil were collected at 10 sites on both the Neoga and Sibley areas during October 1966. The sampling sites, all located in cornfields, were distributed proportionately among the major soil series on each area. At each site, about 15 meters from the edge of the field, a sample of soil from the 0- to 18-cm layer was taken from within 30 cm of the base of what we judged to be a normal corn plant surrounded by clumps of foxtail. Kernels of corn were harvested from the corn plant and seeds were stripped from the associated foxtail plants to complete the sample collection at each site.

Samples of primary feathers were taken from 14 pheasants collected on each area during the autumn of 1966. The feather samples were taken from birds killed by hunters, from birds killed by vehicles on highways, and from birds captured by nightlighting (Labisky 1968:6–8). The collection of pheasants from the Neoga Area included only birds that had been hatched and reared on the area. The depth of the bursa of Fabricius was used to separate juveniles, or young-of-the-year, from adults. The Neoga sample included 12 juvenile males and 2 adult males; the Sibley sample, 11 juvenile males, 1 adult male, and 2 juvenile females.

Analytical Procedures

Soil, including grit, was air dried and ground to pass through a 2-mm mesh screen. A subsample was then taken from each sample and ground until it would pass through a 0.25-mm mesh screen. Calcium and potassium concentrations in the soils were determined by X-ray spectrography; the finely ground soils were compressed into flat discs for analysis. The concentrations of calcium and of potassium were estimated from calibration curves that we derived for each element by analysis of National Bureau of Standards samples and by analysis of standards we prepared by the addition of a salt of the element to soil. Sodium and magnesium concentrations were determined by flame photometry and atomic absorption analysis, respectively, after the soil had been fused with lithium metaborate (Ingamells 1966:1228). A total elemental analysis, rather than plant-available analysis, was per-

formed because we believed it to better represent the minerals to which the pheasant is exposed. Also, a relatively large proportion of the elements in these fine-textured soils occurs in forms available to plants.

The corn and foxtail seeds were oven-dried at 60° C. The corn was finely ground in a Wily mill; the foxtail seeds were left intact (with floret structures attached). Except for calcium in corn, the elemental concentrations in seeds were determined by direct-reading emission spectrography. A rotating-disc solution technique, with a-c spark excitation, was used in the analyses; lithium was the internal standard. The samples were prepared for analysis by ashing 1.5 g of material at 500° C. for 24 hours. The ash was taken up in a solution of 4.5 percent HCl, 1.5 percent HNO_3 (by volume), and 1 percent lithium (as LiCl). The concentration of each element was estimated from calibration curves derived by our analyses of reference plant samples assembled by Kenworthy *et al.* (1956). The calcium content of corn was determined by X-ray fluorescence; the finely ground corn was compressed into disc-shaped pellets for this analysis. The concentrations of calcium in the corn samples were estimated from calibration curves that we derived from analyses of similarly prepared corn samples to which known quantities of calcium had been added.

The feather samples were prepared by clipping the primaries, at the junction of calamus and skin, from the right wing of each pheasant. The clipped feathers were then cut into 4-cm segments. Each sample was then placed in a conical flask, washed several hours in distilled water on a reciprocating shaker (with frequent changes of water), and oven-dried at 60° C. The dried samples, which individually weighed 1.5–2.0 g, were ashed at 500° C. for 36–48 hours. The ash was taken up in hot 6*N* HCl and then filtered. The filtrate was analyzed for sodium and potassium by flame photometry; the concentrations of these minerals were estimated from analyses of standards that we prepared from reagent-grade chemicals to approximate the matrix of the feathers. Atomic absorption analysis was used to determine the amounts of calcium and magnesium in the filtrate; lanthanum chloride was used as the suppressant.

The rationale for using feathers to study the mineral complex in birds was derived from early work on ruffed grouse (*Bonasa umbellus*) in New Hampshire by McCullough and Grant (unpublished[1]) and from the later studies on blue and lesser snow geese (*Anser caerulescens caerulescens*) by Hanson and Jones (1968). In view of the findings of these studies, we considered the concentrations of elements in pheasant feathers to reflect the mineral status of the metabolic pool and interelemental relationships during feather growth.

[1]Studies by Robert A. McCullough and C. L. Grant in 1952 and 1953, involving laboratory analyses of fish and game and their foods, under the auspices of New Hampshire Pittman-Robertson and Dingell-Johnson projects.

FINDINGS

In soils, mean concentrations of potassium, calcium, and magnesium were less, and those of sodium greater, at Neoga than at Sibley. The differences, Neoga versus Sibley, for all four elements were statistically significant (Table 1). These findings illustrate, in a general way, the degree of weathering of the soils on the two areas. Potassium and calcium are among the first elements to respond to weathering processes under Illinois conditions (Jones & Beavers 1966:622). The relatively low concentrations of these alkali and alkaline earth elements in soils at Neoga reflect, in particular, the weathering of calcium-bearing feldspars, magnesium- and potassium-bearing micas, and ferromagnesian minerals. Sodium, which occurs in the sodium-rich feldspar albite that is resistant to weathering, and in rather high levels as an exchangeable cation in planosols, has become relatively concentrated at Neoga.

In corn samples, sodium, potassium, and magnesium, as well as total ash, were more abundant in samples from Neoga than in those from Sibley (Table 1). However, except for the difference in magnesium, none of these differences was statistically significant. The mean concentrations of calcium in corn were low, being only 38 and 31 ppm in the samples from Sibley and Neoga, respectively. Foxtail seeds contained 25–30 times more calcium than corn did on both areas.

In foxtail, potassium and total ash exhibited higher mean concentrations among samples from Neoga than among those from Sibley; the difference for potassium was significant. The high ash content of foxtail, in contrast to that of corn, was due in part to the fact that the entire foxtail floret was ashed. The structures of the floret, compared with the seed, are rich in minerals, particularly silicon. Concentrations of sodium, calcium, and magnesium in foxtail did not differ appreciably between areas.

In pheasant feathers, mean concentrations of all four elements and of total ash were higher for samples from Neoga than for those from Sibley (Table 1). The differences exhibited by sodium, potassium, and magnesium were significant. Sodium was almost five times and potassium about two and one-half times more abundant in feathers from pheasants at Neoga than in those from Sibley pheasants.

The ratio of sodium to potassium was notably greater in soils, foxtail seeds, and pheasant feathers from Neoga than in those from Sibley (Table 2). Although the ratio of calcium to magnesium was greater in soils and corn from Neoga than in those from Sibley, it was identical in foxtail seeds and pheasant feathers from the two areas.

The flow of minerals in the ecosystem—from soil to plants (seeds) to pheasants (feathers)—did not generally reflect a direct relationship (Table 1). The one exception was sodium; it was more abundant in soil

Table 1.—Concentrations of elements in soils, plant seeds (corn and foxtail), and pheasant feathers from an area of high-density pheasant populations (Sibley) and from an area of very low-density pheasant populations (Neoga) in Illinois.

Sample Type and Element	*Neoga Area*					*Sibley Area*					*Test of Means**	
	Number of Samples	Mean	Standard Error of the Mean	Range	Coefficient of Variability	Number of Samples	Mean	Standard Error of the Mean	Range	Coefficient of Variability	Degrees of Freedom	*t* Value
Soil												
ppm Na	10	815	10	740–840	4	10	678	14	590–760	7	18	7.80^{s}
ppm K	10	19,530	420	16,900–20,900	7	10	25,910	640	23,500–29,800	8	18	8.41^{s}
ppm Ca	10	9,350	843	5,000–14,000	29	10	12,550	872	9,300–18,400	22	18	2.64^{s}
ppm Mg	10	860	72	540–1,240	26	10	1,874	139	1,400–2,460	23	9†	6.49^{s}
Corn												
Percent ash	10	2.07	0.27	1.67–2.45	41	10	1.77	0.31	1.23–2.23	56	18	0.73^{ns}
ppm Na	9	71	8	35–120	33	8	60	9	25–93	41	15	0.95^{ns}
ppm K	10	5,150	211	4,200–6,300	13	10	4,540	231	3,700–6,200	16	18	1.94^{ns}
ppm Ca	10	31	3	24–51	25	10	38	2	28–51	19	18	2.00^{ns}
ppm Mg	10	1,640	123	1,100–2,400	24	10	1,170	62	800–1,500	17	18	3.42^{s}
Foxtail												
Percent ash	10	7.20	0.50	4.53–10.04	22	10	6.38	0.10	5.03–8.64	5	18	1.39^{ns}
ppm Na	10	102	25	77–161	78	10	103	5	75–125	17	18	0.15^{ns}
ppm K	10	5,230	268	3,700–6,700	16	10	3,180	216	3,000–5,300	18	18	4.12^{s}
ppm Ca	10	920	36	800–1,200	12	10	910	72	700–1,400	25	18	0.12^{ns}
ppm Mg	10	2,140	54	1,900–2,500	8	10	2,180	144	1,400–3,200	21	18	0.82^{ns}
Feathers												
Percent ash	14	0.37	0.02	0.23–0.54	27	14	0.32	0.03	0.21–0.67	37	26	1.21^{ns}
ppm Na	13	221	6	123–348	10	13	45	8	19–105	17	12†	8.07^{s}
ppm K	14	72	7	10–117	38	14	28	3	17–58	47	13†	5.62^{s}
ppm Ca	14	207	17	118–273	31	14	168	7	114–218	16	13†	2.07^{ns}
ppm Mg	14	111	6	41–126	19	14	83	4	53–114	18	26	4.00^{s}

*All tests at 0.05 level of probability; s denotes significance, and ns, the lack of significance.
†Variances dissimilar; test degrees of freedom equal n−1 rather than 2(n−1).

at Neoga (815 ppm) than at Sibley (678 ppm) and was also more abundant in pheasant feathers from Neoga (221 ppm) than in those from Sibley (45 ppm). Potassium was present in greater concentrations in soils from Sibley (25,910 ppm) than in those from Neoga (19,530 ppm), but was more abundant in foxtail and feathers at Neoga (5,230 and 72 ppm) than at Sibley (3,180 and 28 ppm). Concentrations of calcium were greater in soils from Sibley (12,550 ppm) than in those from Neoga (9,350 ppm), but differed very little in samples of corn, foxtail, and feathers from the two areas. Magnesium was more abundant in soils from Sibley (1,874 ppm) than in soils from Neoga (860 ppm), but was more abundant in corn and feathers from Neoga (1,640 and 111 ppm) than in those from Sibley (1,170 and 83 ppm). Thus, the

Table 2.—Sodium:potassium and calcium:magnesium ratios in soils, plant seeds (corn and foxtail), and pheasant feathers from an area of high-density pheasant populations (Sibley) and from an area of very low-density pheasant populations (Neoga) in Illinois.

Elemental Ratios and Samples	*Neoga Area*				*Sibley Area*				*Test of Means**	
	Number of Samples	Mean	Standard Error of the Mean	Coefficient of Variability	Number of Samples	Mean	Standard Error of the Mean	Coefficient of Variability	Degrees of Freedom	*t* Value
Na/K Ratios										
Soil	10	0.42	0.010	7	10	0.26	0.010	12	18	3.81^{s}
Corn	9	0.01	0.002	37	8	0.01	0.002	40	15	0.28^{ns}
Foxtail	10	0.02	0.003	42	10	0.03	0.002	20	18	2.25^{s}
Feathers	13	2.90	0.150	19	13	1.58	0.128	13	24	6.75^{s}
Ca/Mg Ratios										
Soil	10	10.98	0.699	21	10	7.00	0.633	29	18	4.23^{s}
Corn	10	0.02	0.002	33	10	0.003	0.0101	30	18	2.75^{s}
Foxtail	10	0.43	0.017	13	10	0.42	0.025	19	18	0.33^{ns}
Feathers	14	2.04	0.088	16	14	2.05	0.102	19	26	0.07^{ns}

*All tests at 0.05 level of probability; s denotes significance, and ns, the lack of significance.

differences in concentrations of elements in soils were not directly proportional to the levels in either plant seeds or pheasant feathers.

DISCUSSION

The amounts and rates of flow of minerals through the ecosystem, i.e., from soils to plants to animals and eventually back to soils, have profound and far-reaching effects on all living organisms. In the present study, sodium, potassium, calcium, and magnesium were not, for the most part, incorporated into plant seeds and pheasant feathers in the same proportions that they occurred in soils. For example, significant differences existed in the amounts of potassium in foxtail seeds and of magnesium in corn between the Sibley and Neoga areas. Yet correlation analyses indicated that a significant inverse relationship existed between the concentrations of potassium in soil and in foxtail seeds ($r = -0.445$, 18 df) and between the concentrations of magnesium in soil and in corn ($r = -0.618$, 18 df). Clearly the flow of elements through the environmental complex was not straightforward. As the uptake and use of elements by plants and animals are influenced by many factors, this finding was understandable. Interactions among elements are particularly effective in altering translocation and storage of minerals in plants and animals (Schütte 1964).

The role of calcium is central to the many considerations of ion uptake by plants (Emmert 1961). Calcium is reported to antagonize the uptake of manganese, potassium, iron, boron, zinc, and magnesium in some plant structures (Schütte 1964:41). Correspondingly, we found the concentrations of magnesium in corn were inversely and significantly correlated with the amounts of calcium in this grain ($r = -0.623$, 18 df). Yet we found no significant correlations between soil calcium and the subsequent uptake of potassium by foxtail seed ($r = 0.041$, 18 df) or of magnesium by corn ($r = 0.306$, 18 df). However, these relationships are tempered by the fact that our determinations were for total soil calcium and not for plant-available calcium.

The low levels of calcium in corn, the staple diet of the pheasant, are noteworthy. If pheasants are to obtain a sufficient level of calcium—at least the minimum dietary requirement of 1.2 percent as indicated by Dale and DeWitt (1958 *In* Greeley 1962:186) and Scott *et al.* (1958:1421)—they must obtain it from calcareous grit. To illustrate, if a pheasant consumes 35 g of corn (R. F. Labisky & W. L. Anderson unpublished) containing 35 ppm of calcium per day, its dietary intake of calcium is only 0.0035 percent. To attain the 1.2 percent level, the pheasant must then ingest daily, and totally utilize, 1.04 g of limestone containing 40 percent calcium. In this case, the limestone grit constitutes 99 percent of the pheasant's calcium intake.

The differences detected in the concentrations of potassium, calcium, and magnesium in the soils of the Neoga and Sibley areas (Table 1) illustrate, somewhat axiomatically, that older (Illinoian) glacial drift is relatively poor in three, and probably several more, important inorganic nutrients. These findings support the contention that a deficiency of calcium, and perhaps of other minerals, may limit the distribution of pheasants in many areas in the eastern United States. If, however, pheasants on the Neoga area were suffering from insufficient levels of potassium, calcium, or magnesium, the insufficiencies were not expressed in the mineral composition of their feathers (Table 1).

Inasmuch as Burns *et al.* (1953:327) reported that a wide disparity in the ratio of sodium to potassium was toxic to domestic chicks (*Gallus gallus*), the high ratios of sodium to potassium in soils, foxtail, and pheasant feathers from Neoga suggest that a nutritional imbalance may exist on the Illinoian drift (Table 2). In this particular case, the disparity in the sodium:potassium ratio in soils from Neoga and Sibley (0.42 versus 0.26) was similar to that reflected by the feathers from the respective areas (2.90 versus 1.58). Although calcium:magnesium ratios differed significantly for soils and corn from the two areas, no differences were found for the feathers. Little is known of how the relative levels of these elements affect the uptake and metabolism of other minerals by the pheasant.

None of the elemental differences, as such, found in the soils, plant seeds, or pheasant feathers from the pheasant-poor area on Illinoian drift (Neoga) and from the pheasant-rich area in Wisconsinan drift (Sibley) is satisfactory—with our present knowledge of the mineral needs of pheasants—to explain the magnitude of difference in population levels between the two areas. Nevertheless, differences did exist between the areas in concentrations of sodium, potassium, calcium, and magnesium in soils; of magnesium in corn; of potassium in foxtail; and of sodium, potassium, and magnesium in pheasant feathers. These findings, to our knowledge, represent the first documentation of clear-cut elemental differences in both birds and environment between areas of contrasting pheasant abundance.

SUMMARY

Concentrations of four essential elements—sodium, potassium, calcium, and magnesium—were measured in soils, plant seeds (corn and Chinese foxtail), and pheasant feathers from two areas of contrasting pheasant abundance in Illinois. The low-density pheasant population was located on the geologically older Illinoian glacial drift and the high-density population on the younger Wisconsinan drift. Potassium, calcium, and magnesium were less abundant, and sodium was more abundant, in Illinoian drift soils than in Wisconsinan drift soils. Magnesium was more abundant in corn, and potassium was more abundant in foxtail on the Illinoian drift. And higher concentrations of sodium, potassium, and magnesium were found in feath-

ers of pheasants on the Illinoian drift than from those of pheasants on the Wisconsinan drift. Thus, the differences in the concentrations of elements in soils were mirrored neither in plant seeds nor in pheasant feathers. If pheasants were suffering from a deficiency of calcium, potassium, or magnesium on the more weathered Illinoian drift, the deficiency was not reflected by the mineral composition of their feathers. However, high sodium-to-potassium ratios in soils and feathers on the Illinoian drift, in contrast to those on the Wisconsinan drift, may indicate a nutritional imbalance.

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The Value of IN VITRO FUNGICIDE TESTS

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The Value of IN VITRO FUNGICIDE TESTS

Dan Neely

Because chemists now seem able to synthesize an unlimited number of compounds, we can expect that many fungicides developed in the future will prove to be better than those we are using at the present time. Appropriate methods must be employed to select the better fungicides from among the mass of candidate materials.

Separating the successful and unsuccessful fungicides is an expensive procedure. Wellman (1967) estimated industry's cost of research on one new fungicide to be $3 million. Since it becomes increasingly difficult to find a fungicide that is more successful than one just introduced, these costs can be expected to increase. With this vast expense involved, research agencies must develop and use techniques and methods that are both efficient and reliable.

The three traditional steps in the search for an effective new fungicide are laboratory evaluation, greenhouse evaluation, and field evaluation. With the proper tests and the proper interpretation of the test results, this still seems to be the only practical system. Opinions vary among investigators as to the importance of each of the steps. This paper will review the test methods used to seek and evaluate fungicides in the laboratory, and specifically the in vitro tests. It will be further limited to those methods used to develop protective foliar fungicides. The specialized methods used to develop eradicative, systemic, and soil fungicides are not included.

The value of in vitro tests to appraise fungicides in the laboratory is determined by the ease, speed, and simplicity of test manipulations and the reliability and usability of test results. Alternative in vivo methods are time consuming, which prohibits extensive use of greenhouse and field techniques in the initial evaluation of chemicals. In vivo tests are essential, however, in determining how effectively chemicals control plant diseases.

The literature concerning in vitro testing of fungicides has been reviewed by several investigators (Horsfall 1945*a*, 1945*b*, 1956; McCallan 1947, 1959), most recently by Torgeson (1967). In this paper I wish to emphasize the variety of in vitro techniques that can be used as the basis for selecting fungicides for greenhouse and field studies. Many of these in vitro techniques have additional value, for in recent years they have been extensively used in studies seeking the toxic principles of fungicide groups and the mode of action of chemical structures on plant pathogens.

The significance of fungicide tests in an artificial rather than a natural situation is occasionally questioned. Marsh (1936) and Howard (1939) compared spore germination on leaves and on glass slides and found comparable results. Miller (1943) compared the retention of copper on leaves and on pyralin plates and found laboratory methods to be fairly accurate.

FUNGICIDE-FUNGUS INTERACTIONS

In vitro tests are used to measure and rank the fungitoxicity of fungicides, to measure fungal specificity, and to measure fungicide deposition, redistribution, tenacity, persistence, stability, and volatility.

Chemicals toxic to fungi have been observed to affect the fungi in various ways. The fungus mycelium may cease growing, change metabolic processes, or be killed. The fungus spores may fail to swell before germinating, fail to germinate, plasmolyze, or be killed. Each of these reactions is measurable. Each has been used in the past to determine fungicide toxicity in vitro. Standard methods of determining toxicity have not been universally accepted.

Fungitoxicity

While we accept the general definition of a fungicide as "any substance that destroys fungi or inhibits the growth of the spores or hyphae," we should restrict the use of the adjective *fungicidal* to the conditions that kill fungi and the term *fungistatic* to those conditions that prevent additional growth or sporulation of fungi without killing them (McCallan & Wellman 1942). The term *fungitoxic* has come into use in those situations where detrimental morphological or physiological fungal changes occur but no effort is made to determine whether or not the fungi are killed by the treatment.

Many techniques have been developed during the last 40 years that attempt to measure the fungitoxicity of chemicals or compare the fungitoxic values of chemicals. These techniques are usually bioassays involving a chemical and a test fungus. The use of a fungus introduces biological variability and reduces

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the significance of each measurement of toxicity. Many of the techniques now used have been developed with the express purpose of reducing biological variability.

Testing With Spore Germination.—Early tests of Reddick & Wallace (1910) and McCallan and coworkers (McCallan 1930; McCallan, *et al.* 1941*b*; McCallan & Wilcoxon 1938, 1939; Wilcoxon & McCallan 1939) and Horsfall, *et al.* (1940) were spore germination tests involving the deposition of chemicals on glass slides, evaporation to dryness, and the addition of a drop of water containing spores of the test fungus. The American Phytopathological Society (1943) published instructions for this technique.

One problem encountered with this technique was the variation in size of the water drops. Montgomery & Moore (1938) attempted to solve this by drawing a circle on the glass slide with a diamond pencil, Young (1944) etched a circle with hydrofluoric acid, and Miller (1949) drew a circle with a wax pencil. Others have used depression slides (Barratt & Horsfall 1947, Kirby & Frick 1953, and Prusova 1962), small petri dishes (Tamura 1954), microbeakers (Shafer 1952 and Spencer 1962), or raised cover slips on slides (Peterson 1941).

Another problem was that of obtaining an accurate determination of the amount of toxic material on the slide. Elaborate laboratory sprayers have been built to uniformly deposit the chemical. An alternate solution by McCallan & Wilcoxon (1938) and Peterson (1941) involved mixing the toxicant with the spore suspension directly and not previously forming a dry deposit on the slide. Procedures for this test tube dilution technique were described by the American Phytopathological Society (1947).

Although germinating spores on glass slides are easily examined microscopically, glass is not the ideal substrate for spore germination. Marsh (1936) observed that fungus spores germinated better on glass slides that had been coated with cellulose. Transparent materials other than glass have been successfully used. McIntosh (1961) and Spencer (1962) used transparent plastic polymers. Neely & Himelick (1966) germinated spores on nonwaterproof cellophane discs placed on filter paper pads previously saturated with the toxic solution or suspension. The cellophane discs were transferred to slides for microscopic determination of fungistatic activity or transferred to agar for determination of fungicidal activity.

Many fungus spores do not germinate well in water drops. Davies, *et al.* (1948) found that shaking the culture greatly improved the uniformity of spore germination. Darby (1960) described a shaker method with a 4-hour germination period. Gattani (1954) observed that spores germinate better on agar than in water drops. He mixed the fungicide with warm agar, allowed the agar to solidify, seeded the agar with spores, and counted the germinating spores by placing the petri dish under a microscope. Heyns, *et al.* (1965) placed seeded, toxicant-agar preparations on microscope slides.

Rapid tests involving swelling of spores prior to spore germination also have been used to measure fungitoxicity. Mandels & Darby (1953) described a 3-hour test with the failure of spores to swell as the measurable character. Koopmans (1959) based his results on the loss of turgidity of powdery mildew spores in toxic solutions.

Macroscopic Tests.—Counting germinating spores has always been a tedious, fatiguing task. In vitro tests utilizing macroscopic observations of fungus colony growth have often been used. Lee & Martin (1927) and Wellman & Heald (1940) placed fungus spores in known aqueous concentrations of the toxicant for varying lengths of time before transferring them to bouillon or agar. Their tests are based on reduction in number of fungus colonies formed.

The most commonly used macroscopic tests involve germination of spores on toxicant-agar preparations in petri plates with colony counts being made or the absence of colonies noted (Palmiter & Keitt 1937). With the roll culture technique of Manten, *et al.* (1950), the toxicant-agar layer is formed along the sides of round bottles rather than in petri dishes. A closely related method involves placing known quantities of toxicant at specific spots on seeded agar plates. The fungicide diffuses through the agar. The diameter of the clear area where spore germination was inhibited is measured. The fungicide may be placed in holes in the agar (Mildner, *et al.* 1963) or added with saturated filter paper pads (Thornberry 1950 and Leben & Keitt 1950) or string (Kuhfuss 1957).

In vitro techniques measuring toxicity of chemicals to fungus hyphae are often useful, especially with fungi that fail to sporulate or sporulate poorly in the laboratory. A common procedure is to incorporate toxic materials into agar and then seed with uniform mycelial colonies in agar blocks (Carpenter 1942), on filter paper pads (Sharvelle & Pelletier 1956), or on agar-coated cover slips (Bomar 1962). The reduction in fungus growth is then measured. Fungus cultures on agar plates also have been dusted or sprayed with toxic materials (Henry & Wagner 1940), submerged beneath toxic materials (Grosser & Friedrich 1947), or placed near toxic materials (Moreau & Moreau 1959), after which the resulting inhibition of growth was measured.

The fungus mycelium growing in toxic solutions has been linearly measured (Mason & Powell 1947) and weighed (Le Tourneau & Buer 1961). Forsberg (1949) placed a fungus-infested string in toxic dilutions for varying periods of time, then transferred the string to agar to determine fungicidal activity.

Mandels & Siu (1950) describe fungitoxicity tests

with a manometric system where the growth of the organism is measured by the amount of oxygen absorbed. McCallan, *et al.* (1954) and McCallan & Miller (1957) felt that measurement of oxygen consumption was not a particularly useful means of determining fungitoxicity.

Comparisons of Methods of Testing.—There have been relatively few published reports in which the methods for determining fungitoxicity have been compared. In observations of techniques involving spore germination, Frick (1964) found the test tube dilution test less variable than the dried deposit-slide germination test. Gottlieb (1945) found the seeded, toxicant-agar method and the test tube dilution method equally sensitive. Manten, *et al.* (1950) found the roll culture method more useful than the seeded toxicant-agar, dried deposit-slide germination, and gravimetric methods. Himelick & Neely (1965) found the cellophane transfer technique more sensitive than the seeded agar-toxicant spot method. Walker (1955) compared spore germination, spore respiration, and mycelia respiration techniques and found that, in general, the three methods gave the same ranking of fungicides.

Measurements.—In establishing the value of fungitoxicity tests we must not only know the method of testing but also the method of measurement and the means of expressing the resulting data. In bioassays this is a difficult task. McCallan and his co-workers have found that the amounts of fungicides absorbed by spores of different fungal species vary greatly and suggest that possibly fungitoxicity should not be based on the concentration of the external solution or suspension but on the weight of toxicant actually absorbed by the fungus (McCallan & Miller 1958; Miller, *et al.* 1953).

One problem encountered with the dried deposit-slide germination technique was whether to express the results in terms of weight of toxicant per unit area of slide or weight of toxicant per unit volume of water. Since the amount of toxicant in solution was not readily known, the results were usually expressed in weight per unit area.

A second problem in giving the results with spore germination tests was how to express the percentage of germination at different fungicide concentrations. It could be shown graphically with ease using a dosage-response curve, but it was difficult to express verbally. McCallan & Wilcoxon (1938) used the term LD50 for that toxic concentration at which there was a reduction of 50 percent in spore germination. Later they used logarithmic paper to estimate the LD50 (Wilcoxon & McCallan 1939), more appropriately called the ED50 (McCallan 1948).

Interpretations of the role of the dosage-response curve in the evaluation of fungicides and the increasingly elaborate statistical methods that accompanied use of the dosage-response curve were the subjects for numerous research papers from 1940 to 1960 (Dimond, *et al.* 1941; Horsfall 1956; Litchfield & Wilcoxon 1949; McCallan, *et al.* 1959). In many reports written during this period the results were expressed in a statistical language unreadable by many plant pathologists. Kundert (1956) commented on the exaggerated application of statistics in the assay of fungicides. Many researchers are now reporting results as the lowest external concentration that completely inhibits spore germination or mycelial growth expressed in parts per million or its equivalent (Guillemat & Lambert 1960; Pianka, *et al.* 1966; Luijten & van der Kerk 1961; Neely & Himelick 1966; Nisikado, *et al.* 1951; Pluijgers & Kaars Sijpesteijn 1966).

Fungal Selectivity

Although phycomycetes, powdery mildew fungi, other ascomycetes, and basidiomycetes are not equally sensitive to fungicides and although certain fungi are sensitive or resistant to specific fungicides (Horsfall 1951; Horsfall & Lukens 1966; Wellman & McCallan 1943), most fungicides now in commercial use have a broad spectrum of activity against fungal species. The test organism commonly used in the laboratory will often rank candidate fungicides in the same order as a specific disease-causing organism. McCallan, *et al.* (1941*a*), in a spore germination test with 6 fungi and 20 compounds, reported the fungi similarly sensitive. Neely & Himelick (1966), in a test with 7 fungi and 24 compounds, in general confirmed these results. Casarini & Pucci (1957) in a test with 6 fungi and 6 compounds felt the resulting differences between fungi sufficiently variable to recommend that the same fungus be used in in vitro trials as in field trials whenever possible.

Deposition, Redistribution, Tenacity, Stability

To be successful a fungicide must prove itself on a natural surface and in a natural environment. This involves the physical and chemical factors of deposition, redistribution, tenacity, and stability (Burchfield 1960, 1967). Modifications of the basic fungitoxicity methods have been developed with the aim of learning as much as possible about these additional factors in the laboratory.

Redistribution of a fungicide is often essential for control of a disease because plant growth, poor tenacity, or poor coverage may leave the fungicide particles widely distributed. Powell (1961) measures the ability of fungicides to redistribute by placing a known fungicide concentration in one depression of a glass slide and a spore suspension in the second de-

pression, making a water bridge between the two with filter paper, and measuring the decrease in spore germination.

The tenacity of fungicide deposists on glass slides was measured by Heuberger (1940) by dipping and swishing the slides several times in water, allowing them to dry, and seeding with a spore suspension. Chapman, *et al.* (1950) suspended the slides in circulating water and removed them at varying intervals of time before drying and seeding. Kovacs (1961) applied the fungicides on polyethylene discs, sprayed them with artificial rain, and placed the discs on seeded agar.

The stability of fungicide deposits on glass slides was measured by Barratt (1946) by subjecting them to high humidity and seeding with spore suspensions. Serra (1964) exposed polyethylene discs dusted with fungicides to ultraviolet light for varying periods of time, then transferred the discs to seeded agar. Ciferri, *et al.* (1961) found that zineb frequently increased in fungitoxicity after 2 to 6 years storage although chemical tests showed a decrease in the amount of "active ingredient."

Predicting Field Performance

In vitro fungitoxicity studies are often used as a means of predicting the field performance of candidate fungicides. The literature relating to predicting field performance from laboratory tests has been reviewed by Ciferri (1952), Rich, *et al.* (1953), McCallan (1959), Block (1959), and Torgeson (1967).

Horsfall and his co-workers were among the first to state that the protective value of fungicides could be predicted on the basis of laboratory results. Horsfall, *et al.* (1941) felt that fungitoxicity and tenacity were the two fundamental components of protective value. Keil, *et al.* (1952) called attention to the necessity of chemical stability. Waggoner, *et al.* (1952) later stated that a statistical prediction of field performance could be made on the basis of toxicity, tenacity, and stability of fungicides.

The relationships between laboratory and field results are not always clear cut. A hesitancy to predict field results from laboratory tests often arises in conversations or personal correspondence, but is infrequently found in the literature. Martin (1942), however, stated that to expect a simple correlation between fungitoxicity alone and field performance is too ambitious. Smith & Read (1961), in studies with the cucumber powdery mildew fungus, found a great variance between laboratory and field results.

Yet, in vitro bioassays often correlate well with field trials. Holloman & Young (1951) reported that laboratory assay was a reliable criterion for field performance for control of Botrytis leaf spot on gladioli. Klomparens & Vaughn (1952) reported field and laboratory trials very consistent for control of Helminthosporium on bent grass. Brook (1957) found that laboratory and greenhouse experiments rated fungicides in almost the same order for control of Botrytis gray mold on tomatoes. Monroe (1963), in studies on bean powdery mildew and bean rust, stated that in vitro and in vivo methods generally ranked the fungicides in the same order. Misato (1963), in studies on rice blast, found the in vitro methods measuring inhibition of mycelial growth and spore formation to be satisfactorily correlated with field results.

Although a prediction based on in vitro tests may prove erroneous on a particular host with a particular set of environmental conditions in the field, the success or failure of the fungicide can often be explained with confidence if a sufficiently varied group of in vitro tests have been performed. Most researchers seeking protective fungicides at least agree with the statement that in vitro testing will result in the selection of chemicals worthy of greenhouse and field testing.

FUNGICIDE-FUNGUS-HOST INTERACTIONS

In vitro tests in the laboratory will not in the foreseeable future replace greenhouse and field trials (Hamilton 1959 and McCallan 1966). An effort is being made, however, to introduce a plant or plant part into in vitro tests so that the reactions of fungicide, fungus, and plant are present. Leben (1949) sprayed leaf discs with an antibiotic, then transferred the leaf discs to seeded agar to determine if the material remained fungitoxic. Leben & Keitt (1949) applied artificial rain to fungicide-treated leaf discs to see if the material was tenacious. Chaves (1954) evaluated the effects of fungicide stickers in much the same manner. Adams, *et al.* (1951) devised a leaf punch so that numerous leaf samples with uniform areas could be easily obtained for use in fungicide bioassays.

The ultimate step in in vitro testing is not simply a bioassay using a plant part, but the prevention of the disease itself. Schmidt (1951) treated the primary leaves of celery with fungicides, inoculated with *Septoria apii,* and obtained results on protective fungicides within 2 weeks. The laboratory fungicide trials of Hislop & Park (1962), using detached, treated, and inoculated pods of *Theobroma cacao,* correlated well with field tests for control of *Phytophthora palmivora.* Horn (1964) described a similar detached cucumber leaf method for screening fungicides for control of cucumber anthracnose. Niemann & Dekker (1966) described a method of evaluating compounds for control of powdery mildew of cucumber by floating leaf discs treated with fungicides on water, inoculating, and observing disease symptoms.

CONCLUSIONS

In vitro fungicide tests are extensively used in the initial evaluation of potentially valuable fungicides. In recent years these tests have provided valuable information on the toxicity of various chemical structures and their modes of action against fungi.

The methods of testing to determine the fungitoxicity of chemicals are extremely varied and are constantly changing. This probably means that an acceptable method that can be universally used as a standard procedure is yet to be developed. The procedures for fungicide testing should be quick, easy, and simple and the results should be reliable, reproducible, and usable.

In vitro fungicide tests are used not only to determine fungitoxicity of test chemicals but also range and degree of susceptibility of fungi, deposition and redistribution of fungicides, stability to resist chemical change, tenacity to resist rainfall and wind, and persistence to resist other degrading elements. The results from these in vitro tests often will explain why a fungicide performed well or poorly in the field.

When a varied group of in vitro tests are performed in the laboratory, the candidate fungicides most likely to give satisfactory protection to plants will be selected for continued greenhouse and field testing. Not all of the complex chemical and environmental conditions of disease development can be reproduced either in the laboratory or the greenhouse. The introduction of plants or plant parts into in vitro tests does more closely approach natural conditions, and the use of these techniques will probably increase in the future.

At present there are no practical substitutes for in vitro tests for the initial screening of candidate fungicides. Thus these tests are invaluable as one of a series of steps required in the evaluation of fungicides.

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RENDS IN PHEASANT ABUNDANCE
N ILLINOIS: 1958 to 1968

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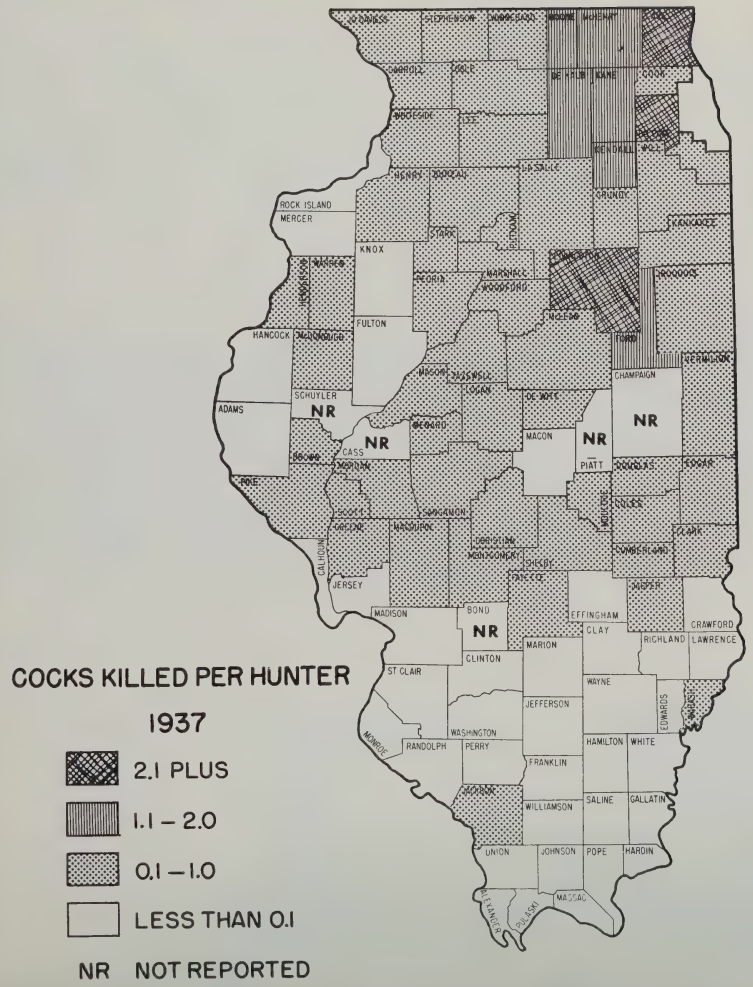

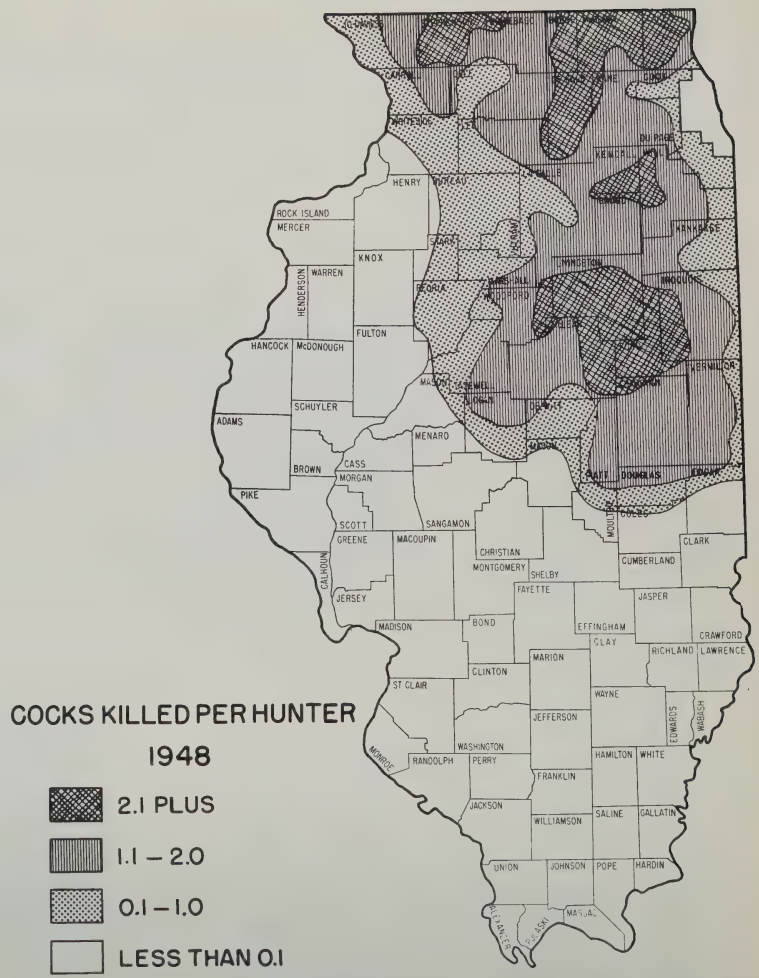

Fig. 1.—Distribution and abundance of pheasants in Illinois as mapped from data obtained (left) from hunting license questionnaires for the 1937 pheasant hunting season (after Carl O. Mohr, unpublished) and (right) from posthunting season questionnaires distributed to slightly misrepresent statewide pheasant distribution because some hunters very likely reported their seasonal kill of cocks for their counties of residence rather than for the counties where they hunted.

Trends in Pheasant Abundance in Illinois: 1958 to 1968

Ronald F. Labisky

The pheasant *(Phasianus colchicus)*, first introduced into Illinois about 75 years ago (Robertson 1958:3), has established thriving populations in northern and east-central Illinois. It has never established permanent populations in the west-central and southern counties of the state. Although the pheasant has exhibited shifting patterns of population density within its occupied range in the state, it has persistently maintained its center of abundance in the cash-grain region of east-central Illinois since the mid-1930's (Fig. 1; Greeley *et al.* 1962:13–16; Labisky & Anderson 1965:128). The rapid increase in the acreage of row crops (corn and soybeans) in the east-central sector of the state during the 1960's (Joselyn *et al.* 1968: 217–218) has resulted in a marked reduction of pheasant nesting cover, particularly tame hay and small grains. These land-use changes have adversely affected pheasant abundance in this region (Labisky 1968:353–359).

The purpose of this paper is to document the patterns of distribution and abundance of pheasants in Illinois for 1968 and to compare these findings with similar statistics from 1958 and 1963. Some data from the 1958 and 1963 censuses have been presented, in part, in previous publications (Greeley *et al.* 1962; Labisky & Anderson 1965).

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William L. Preno, Illinois Department of Conservation, Springfield, and my Illinois Natural History Survey colleagues, William L. Anderson and Glen C. Anderson, read the manuscript. Richard M. Sheets, Survey Illustrator, prepared the maps and designed the cover. Robert M. Zewadski, Survey Associate Editor, edited the manuscript. Dawn A. Labisky assisted in assembling the materials for distribution to the postmasters and rural mail carriers.

METHODS

Statistics on the distribution and abundance of pheasants reported in this paper were *voluntarily* collected by rural mail carriers during 5-day census periods in April of 1958, 1963, and 1968. These censuses were restricted to the 74 northernmost counties of the state; Greeley *et al.* (1962:14), after conducting a statewide census in 1957, conservatively classified the remaining 28 of Illinois' 102 counties as nonpheasant range. The censuses were conducted in April because Greeley *et al.* (1962:5) concluded: "The conditions for observing pheasants [in Illinois] are probably more nearly constant from year to year in April than in any other month." The specific 5-day census periods (Monday through Friday) were April 21–25 in 1958 and April 22–26 in 1963 and 1968. The daily census period was between 8 AM and noon (CST) in all years.

Approximately 5 days preceding each of the censuses, a packet of materials relating to the census was mailed to the postmaster of each post office having one or more rural routes in the 74 counties to be censused. The packet contained a letter of instruction to the postmaster and a letter of instruction plus a postal-card questionnaire for each rural mail carrier. The postmaster was requested to distribute the latter to each of his rural carriers. Each carrier was asked to report the counties and political townships in which his route was located, the length of his route in miles, and the number of pheasants (cocks and hens) observed along the route on each of the 5 consecutive days specified in the instructions.

The number of miles driven and the number of pheasants seen during the 5-day census period were used to calculate the number of pheasants observed per 100 miles of driving in each township and county. When the route of a mail carrier extended into two or more townships, the number of miles driven and number of pheasants observed were divided equally among the number of townships that he reported on his questionnaire. The variables that influence the counts of pheasants by rural mail carriers have been discussed by Greeley *et al.* (1962:4–5).

The information reported by mail carriers during each census was the result of the initial request only; follow-up mailings to prompt the return of questionnaires were unnecessary (Table 1). To exemplify, in 1968, 97 percent of all returned questionnaires had been received by May 1—only 5 days after the last day of the census period. After each census all postmasters and mail carriers participating in the census were sent a summary of the census findings and a letter thanking them for their cooperation.

FINDINGS

The relative abundance of pheasants in the 74 northernmost counties of Illinois increased from 7.6 to 9.9 pheasants observed per 100 miles of driving (30 percent) between April, 1958, and April, 1963, and then declined to 5.5 birds per 100 miles (44 percent) by

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Table 1.—Comparative statistics obtained from rural mail carrier censuses of pheasants in the 74 northernmost counties (including 1,257 townships) of Illinois during designated 5-day census periods in April of 1958, 1963, and 1968.

Category	April, 1958	April, 1963	April, 1968
Questionnaires mailed	1,368	1,320	1,256
Number returned	1,053(77)*	1,202(91)	1,143(91)
Number usable (of total)	†	1,150(87)	1,105(88)
Number of townships reported (of 1,257)	1,221(97)	1,222(97)	1,214(97)
Total miles driven	250,129‡	318,605	333,070§
Miles driven per township reported	205	261	268
Cocks observed	10,047‡	17,204‡	10,706
Hens observed	9,044‡	14,466	7,545
Total pheasants observed	*19,091‡*	*31,670‡*	*18,251*
Sex ratio: hens per cock	0.9	0.8	0.7
Cocks per 100 miles	4.0‡	5.4	3.2
Hens per 100 miles	3.6‡	4.5	2.3
Total pheasants per 100 miles	*7.6‡*	*9.9*	*5.5*

* Percentages are given in parentheses.
† Data are not available.
‡ These figures are slightly different from those appearing in Labisky and Anderson (1965:129, Table 1); the figures in the earlier publication were in error.
§ 8,233 miles of driving were, for the lack of township designations, assigned only to counties.

April, 1968 (Table 1). Statistics for hens only, em ployed to avoid sex-ratio differences among years, re vealed similar trends in abundance. The number o hens observed per 100 miles increased from 3.6 in 195 to 4.5 in 1963 (25 percent) and then declined to 2.3 her per 100 miles in 1968 (49 percent). Thus, pheasant increased in abundance by about one-fourth betwee 1958 and 1963 and declined in numbers by almost one half in the succeeding 5 years, 1964–1968. Pheasant were only about three-fourths as abundant in 1968 a in 1958.

Although the overall trend in pheasant abundanc in Illinois during the past decade was downward, no all portions of the occupied range suffered declines i abundance. In fact, the pheasant range can be sepa rated into three major sectors with respect to change in abundance that have occurred within the past 1 years. The east-central portion of the state showe substantial gains (about 50 percent) in abundance be tween 1958 and 1963; however, the marked declin (about 60 percent) in abundance between 1963 an 1968 more than cancelled the earlier gains, resulting i a net loss of pheasants in Illinois' prime range (Tabl 2; Fig. 2–4). All counties of northern Illinois, excep Carroll, were characterized by substantial losses i pheasant abundance between 1958 and 1968; the losse incurred between 1958 and 1963 were particularly se vere. In contrast, the southern and southwestern por tions of the range occupied by pheasants in Illinois wer characterized by very substantial gains in abundanc between 1958 and 1968.

Table 2.—Relative abundance of pheasants as reported by rural mail carriers in the 74 northernmost counties of Illinois i April 1958, 1963, and 1968. The remaining 28 counties, located in southern Illinois, are not occupied by pheasants.

County	County Rank			Total Pheasants Reported			Pheasants Per 100 Miles			Percentage Change Per 100 Miles		
	1958	1963	1968	1958	1963	1968	1958	1963	1968	1958 to 1963	1963 to 1968	1958 to 1968
Livingston	1	1	1	3,634	8,181	3,006	56.4	99.1	33.3	+76	−66	−4
Logan	16	17	2	305	345	1,543	8.3	9.7	31.1	+17	+221	+27
Ford	2	2	3	1,569	2,696	1,144	50.7	75.8	29.2	+50	−61	−4
Woodford	7	7	4	718	852	787	15.6	21.8	21.4	+40	−2	+3
Moultrie	37	15	5	27	301	554	1.4	11.3	18.1	+707	+60	+1,19
Piatt	12	6	6	305	986	402	11.8	34.6	17.7	+193	−49	+5
McLean	4	4	7	2,071	3,868	1,324	27.7	43.1	17.0	+56	−61	−3
Champaign	5	5	8	1,641	3,018	1,371	25.7	35.6	16.8	+39	−53	−3
Iroquois	3	3	9	1,991	3,674	1,373	28.9	43.4	15.7	+50	−64	−4
De Witt	19	11	10	190	547	405	6.5	16.1	12.2	+148	−24	+8
Putnam	13	9	11	81	131	105	10.8	19.1	10.6	+77	−44	−2
Kankakee	8	8	12	706	973	538	15.3	19.7	10.1	+29	−49	−3
Vermilion	6	16	13	966	728	632	17.3	11.1	9.8	−36	−12	−4
Grundy	10	10	14	323	429	283	12.5	17.7	9.3	+42	−47	−2
La Salle	11	14	15	873	1,233	820	12.4	13.8	9.1	+11	−34	−2
Douglas	15	13	16	204	487	244	8.7	14.3	8.6	+64	−40	−1
Macon	42	19	17	27	326	421	0.7	6.6	8.5	+843	+29	+1,11
Marshall	9	12	18	328	395	176	14.6	15.0	8.2	+3	−45	−4
De Kalb	14	21	19	367	261	396	10.4	5.2	8.0	−50	+54	−2
Tazewell	21	18	20	284	343	356	6.1	8.5	6.5	+39	−24	+7
Mason	30	20	21	66	148	184	2.7	5.4	6.4	+100	+19	+13
Edgar	24	24	22	190	214	258	5.0	4.2	5.3	−16	+26	+6
Kendall	17	22	23	135	131	148	7.4	4.8	5.0	−35	+4	−3
Christian	52	32	24	9	67	204	0.2	1.2	3.5	+500	+191	+1,65
McHenry	18	25	25	280	200	183	7.0	3.9	3.4	−44	−13	−5
Coles	31	29	26	60	86	128	2.0	2.3	3.2	+15	+39	+6
Lee	20	26	27	243	147	131	6.2	3.1	2.8	−50	−10	−5
Will	26	27	28	208	179	181	4.6	3.0	2.7	−35	−10	−4

The drastic decline in pheasant abundance in east-entral Illinois, which has harbored perhaps as many s two-thirds of the state's pheasant population during he past 30 years, is of critical interest. In both 1958 nd 1963, the east-central counties of Livingston, Ford, roquois, McLean, and Champaign were, in that order, he five top-ranked counties with respect to relative bundance of pheasants (Table 2). The relative abun-ance of pheasants observed in these counties, collec-vely, was 37.9 and 59.4 birds per 100 miles in 1958 nd 1963, respectively. In 1968, these same five coun-es had a collective relative density of 22.4 pheasants er 100 miles, a decline of 62 percent from 1963. Fur-thermore, by 1968 McLean, Champaign, and Iroquois counties had slipped from their traditional positions among the five top-ranked counties to occupy positions 7, 8, and 9, respectively. Notably, the only segment of range in Illinois to register a measure of abundance exceeding 100 pheasants per 100 miles of driving in 1958, 1963, and 1968 was that located at the junction of Champaign, Vermilion, Douglas, and Edgar counties (Fig. 2–4).

Northern Illinois, characterized by secondary centers of pheasant abundance in the 1940's (Fig. 1), has, in the intervening years, suffered a greater proportionate loss in pheasant numbers than any other sector of the

Table 2.—(Continued)

County	County Rank			Total Pheasants Reported			Pheasants Per 100 Miles			Percentage Change Per 100 Miles		
	1958	1963	1968	1958	1963	1968	1958	1963	1968	1958 to 1963	1963 to 1968	1958 to 1968
enard	43	34	29	8	18	49	0.6	1.0	2.3	+67	+130	+283
oone	23	35	30	112	21	35	5.1	1.0	2.3	−80	+130	−55
gle	35	41	31	76	26	119	1.5	0.5	2.0	−67	+300	−33
arroll	33	33	32	40	39	65	1.9	1.1	2.0	−42	+82	+5
ane	28	28	33	116	98	67	3.6	2.7	1.7	−25	−37	−52
ngamon	47	38	34	17	43	101	0.3	0.6	1.5	+100	+150	+400
ook	29	30	35	92	61	54	2.8	1.6	1.4	−43	−12	−50
ass	53	36	36	4	18	32	0.2	0.8	1.2	+300	+50	+500
u Page	25	23	37	93	117	35	4.9	4.3	1.2	−12	−72	−76
ake	32	31	38	60	66	54	2.0	1.2	1.1	−40	−8	−45
areau	38	42	39	66	29	70	1.3	0.5	1.0	−62	+100	−23
innebago	36	37	40	46	22	39	1.5	0.6	1.0	−60	+67	−33
ephenson	22	44	41	201	18	38	5.4	0.3	0.9	−94	+200	−83
Whiteside	48	47	42	15	13	39	0.3	0.3	0.8	0	+167	+167
elby	54	39	43	11	35	40	0.2	0.5	0.7	+150	+40	+250
organ	57	48	44	2	5	14	0.1	0.2	0.4	+100	+100	+300
ercer	55	43	45	2	15	14	0.1	0.5	0.4	+400	−20	+300
enry	34	46	46	88	19	16	1.8	0.3	0.3	−83	0	−83
ontgomery	60	54	47	3	4	16	0.1	0.1	0.3	0	+200	+200
Daviess	39	45	48	37	15	11	1.2	0.3	0.2	−75	−33	−83
ark	27	40	49	63	9	7	4.2	0.5	0.2	−88	−60	−95
acoupin*		59	50	0	1	8	0.0	0.0+	0.1	−†	+	+
umberland	50	58	51	6	2	3	0.3	0.1	0.1	−67	0	−67
ulton	64		52	1	0	5	0.0+	0.0	0.1	−	+	+
ock Island	59	52	53	3	2	3	0.1	0.1	0.1	0	0	0
oria	46	49	54	16	6	3	0.4	0.1	0.1	−75	0	−75
nox	62	57	55	2	3	2	0.0+	0.1	0.1	+	0	+
fingham	41	56	56	24	2	2	0.8	0.1	0.0+	−	−	−
enderson	45		57	10	0	1	0.5	0.0	0.0+	−	0	−
ancock			58	0	0	2	0.0	0.0	0.0+	0	+	+
sper	40	50	59	33	4	2	1.0	0.1	0.0+	−	−	−
arren	49	55	60	9	3	2	0.3	0.1	0.0+	−	−	−
awford			61	0	0	1	0.0	0.0	0.0+	0	+	+
lams			62	0	0	1	0.0	0.0	0.0+	0	+	+
cDonough	44		63	19	0	1	0.6	0.0	0.0+	−	+	−
nd			64	0	0	1	0.0	0.0	0.0+	0	+	+
ark	56	51	65	3	5	1	0.1	0.1	0.0+	0	−	−
yette	61		66	4	0	1	0.1	0.0	0.0+	−	+	−
ay	51			5	0	0	0.3	0.0	0.0	−	0	−
eene	58	53		2	3	0	0.1	0.1	0.0	0	−	−
rsey		60		0	1	0	0.0	0.0+	0.0	+	−	0
adison‡		61		0	1	0	0.0	0.0+	0.0	+	−	0
ke	63			1	0	0	0.0+	0.0	0.0	−	0	−
own				0	0	0	0.0	0.0	0.0	0	0	0
huyler				0	0	0	0.0	0.0	0.0	0	0	0
ott				0	0	0	0.0	0.0	0.0	0	0	0

* No rank was assigned to counties from which pheasants were absent in year of census.
† Percentage change presented only as + (gain), − (loss), or 0 (no change) for those counties from which pheasants were reported absent cluding 0.0 +) in any of the three census periods.
‡ Richland County was censused in place of Madison County in 1958.

state's pheasant range (Fig. 2–4). Although the pheasant population in northern Illinois had already declined by 1958, it diminished even more during the past decade. The abundance of pheasants in all counties of northern Illinois, except Carroll, diminished substantially between 1958 and 1968; losses in abundance during these 10 years exceeded 50 percent in Jo Daviess, Stephenson, Boone, McHenry, Kane, Cook, Du Page, Lee, Henry, and Stark counties (Table 2). Pheasant populations in northern Illinois would have plummeted even lower had not such counties as Carroll, Stephenson, Winnebago, Boone, De Kalb, and Ogle actually registered gains in abundance between 1963 and 1968.

The most spectacular change in pheasant abundance that has occurred in Illinois within the past decade has been the increase in pheasant numbers in a block of nine counties—Logan, Moultrie, De Witt, Macon, Mason, Christian, Menard, Sangamon, and Cass—situated south and southwest from east-central Illinois. Increases in abundance among these nine counties, all of which had densities of more than one pheasant per 100 miles of driving in 1968, ranged from twofold to sixteenfold during the 10 years, 1958–1968 (Table 2; Fig. 2–4). Notably, two of these counties—Logan and Moultrie—advanced from their respective county rankings of 16 and 37 in 1958 to rankings of 2 and 5 in 1968; these advances in ranking were due not only to gains in abundance recorded in the two counties but also to declines in abundance in many of the previously top-ranked counties. Several counties that adjoin the nine-county sector, namely Piatt, Tazewell, Edgar, and Coles, also posted substantial, though proportionately smaller, gains in pheasant abundance during the past decade.

No decisive spread of pheasants into unoccupied range along the southern and western boundaries of the contiguous pheasant range has occurred within the past decade (Fig. 2–4). Yet pheasant abundance in many segments of this so-called "marginal" range, particularly in the south, has increased in recent years. The several small populations of pheasants beyond the contiguous range could be precursory, self-maintaining flocks, but are probably the artifacts of local releases of artificially propagated birds.

DISCUSSION

Examination of records documenting the distribution and abundance of pheasants since their introduction into Illinois (Greeley *et al.* 1962), leaves little doubt that the state's all-time high in pheasant abundance was attained in 1962 or 1963. This conclusion is substantiated by the fact that the calculated autumn kill of cocks by hunters in Illinois was greater in these years—989,000 in 1962, and 1,066,000 in 1963—than in any preceding or following year through 1968 (William L. Preno, Illinois Department of Conservation, unpublished). The low in pheasant numbers in Illinois during the pas

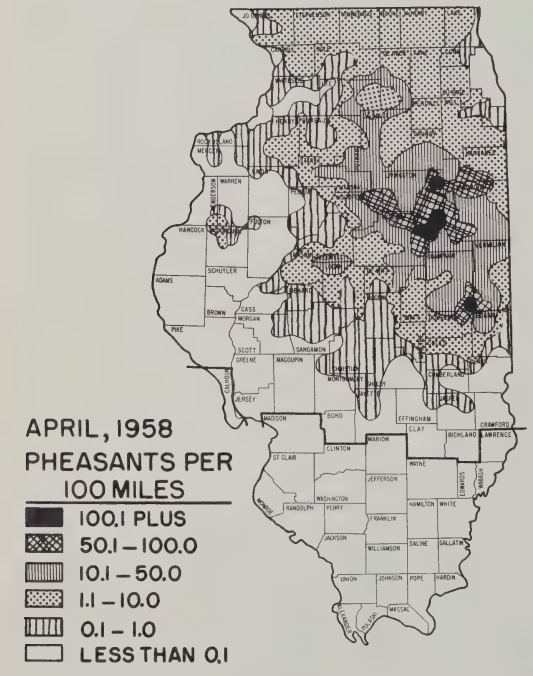

Fig. 2.—Distribution and abundance of pheasants in Illinois as mapped from township statistics obtained by a rural mail carrier census, April, 1958 (after Labisky and Anderson 1965). Counties below the heavy line were not censused.

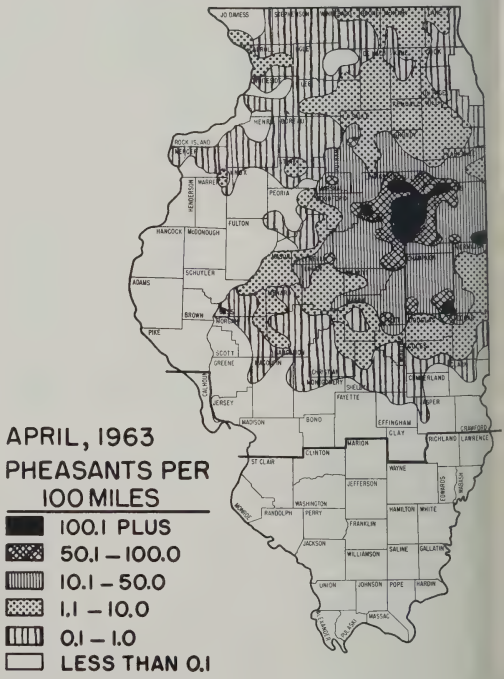

Fig. 3.—Distribution and abundance of pheasants in Illinois as mapped from township statistics obtained by a rural mail carrier census, April, 1963 (after Labisky and Anderson 1965). Counties below the heavy line were not censused.

decade occurred in 1966; the 1968 breeding population was estimated to be about 10 percent above that of 1966 (William L. Preno, unpublished).

In the 5 years following the pheasant high of 1963, the abundance of pheasants in Illinois declined by about 50 percent. Much of this decline in abundance,

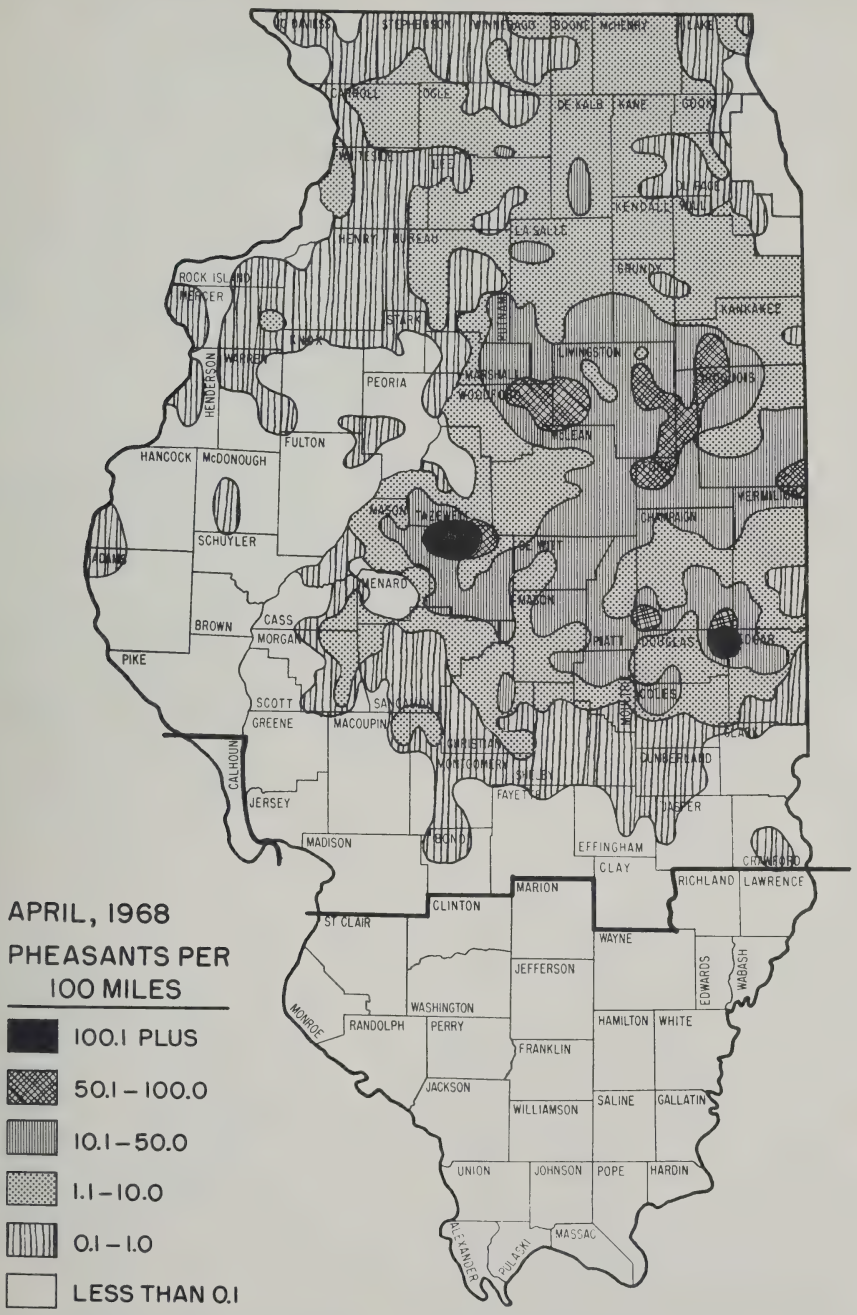

Fig. 4.—Distribution and abundance of pheasants in Illinois as mapped from township statistics obtained by a rural mail carrier census, April, 1968. Counties below the heavy line were not censused.

particularly in the prime pheasant range in east-central Illinois, resulted from the rapid decrease in acreages of tame hays and other suitable nesting habitats. The increase in acreages planted to the major cash-grain crops, corn and soybeans, has brought about this decrease in nesting habitats (Labisky 1968:353–389; Joselyn *et al.* 1968:217–218). The drought of 1964 depressed pheasant production and also contributed to the decline in abundance.

It is most unlikely that substantial gains in pheasant abundance will occur in east-central Illinois in future years unless there is a reversal of agricultural trends, which seems most improbable. In fact, it is doubtful that pheasants will be able to maintain existing population levels for long under today's farming practices. To illustrate, the obvious fragmentation of Illinois' good pheasant range in 1968, as evidenced by the interspersion of areas of lower pheasant abundance with those of higher abundance (Fig. 4), suggests that further declines in abundance will be forthcoming. Livingston County, the top-ranked pheasant county in the state, shows signs of being cleaved from northwest to southeast by a trough of lower pheasant abundance. Other top-ranked counties, notably Champaign, Iroquois, and McLean, exhibited noticeable range fragmentation between 1963 and 1968 (Fig. 3 and 4).

In 1968 the only sector of pheasant range in the state showing encouraging increases in pheasant numbers was in that block of counties (Logan, Moultrie, De Witt, Macon, Mason, Christian, Menard, Sangamon, and Cass) constituting the southwestern portion of Illinois' occupied pheasant range. Gains in pheasant numbers in this area, much of which was classified as mediocre to poor with respect to abundance as recently as the early 1960's, were unusually great (Table 2; Fig. 2–4). In fact, within this sector of pheasant range a secondary center of abundance has appeared in northern Logan County. Not only did this southwest sector of range contain more pheasants in 1968 than it ever had, but it also contained the highest density of pheasants ever recorded along such a broad front so far south in Illinois. Similarly, a surge in pheasant abundance, beginning in the late 1950's, occurred in an area of traditionally poor pheasant range in southwestern Iowa (Klonglan 1962); this buildup in pheasant numbers has already persisted for a decade.

A decisive southward shift in pheasant abundance has occurred in Illinois from 1948 to 1968. Northern Illinois, which contained strong secondary centers of pheasant abundance in the late 1940's, had, by 1968, exhibited greater proportionate declines in pheasant numbers than any other major region of the state. As pheasant abundance declined in northern Illinois, it increased in the prime range of east-central Illinois—reaching an all-time high about 1963. Yet in 1968, east-central Illinois, despite sustaining a 60-percent decline in the pheasant population from that of 1963, still contained the state's center of pheasant abundance as it had in the preceding 30 years. However, during the 1960's a comparatively spectacular gain in abundance occurred in a large and contiguous segment of range located south-southwestward from east-central Illinoi and north of the southern boundary of the contiguou pheasant range in Illinois. If pheasant abundance con tinues to dissipate in east-central Illinois as a result o current agricultural practices, the southwestern portio of range may replace east-central Illinois as the state' center of pheasant abundance. Even though popula tion abundance has increased along the southernmos boundary of the pheasant's range in Illinois in recen years, there has been no real southward extension o the bird's range in the state.

SUMMARY

The relative abundance of pheasants per 100 mile of driving in the 74 northernmost counties of Illinois as reported by rural mail carriers during April censuses was 7.6 in 1958, 9.9 in 1963, and 5.5 in 1968. Thus pheasants increased in abundance by about 30 percent between 1958 and 1963 and then declined by abou 44 percent between 1963 and 1968. The all-time high in pheasant abundance in Illinois was probably reached in 1962 or 1963.

Although the number of pheasants in Illinois has declined during the past decade, not all portions of the state's pheasant range have suffered similarly. Pheasant abundance in east-central Illinois, the state's prime pheasant range since the 1930's, increased about 50 percent between 1958 and 1963 and then declined by about 60 percent between 1963 and 1968. Pheasants in northern Illinois were less than half as abundant in 1968 as in 1958. In contrast, a severalfold increase in pheasant abundance occurred between 1958 and 1968 in a large, contiguous unit of range immediately south-southwestward from east-central Illinois.

Notably, Illinois has experienced a significant, progressive southward shift in pheasant abundance within the past 20 years. Yet, despite the recent surge in pheasant abundance in the southern portion of the range occupied by pheasants, there has been no permanent southward extension of the birds' range in the state.

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TREE AND SHRUB HOSTS OF *Verticillium albo-atrum*

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TREE AND SHRUB HOSTS OF *VERTICILLIUM ALBO-ATRUM*

E. B. Himelick

Verticillium wilt, caused by *Verticillium albo-atrum* Reinke and Berth., has become increasingly prevalent among plantings of ornamental trees and shrubs in Illinois. Persons not familiar with Verticillium wilt symptoms frequently attribute plant deaths resulting from this disease to other causes, such as transplanting shock and winter injury. Because this fungus affects a wide range of woody ornamental plants, it is difficult to estimate the economic loss it causes to nurserymen and homeowners. Rankin (1914) first reported the disease on maple in the United States and identified the fungus as a species of *Acrostalagmus*. Zimm (1918) later proved pathogenicity and identified the fungus as a species of *Verticillium*. A monograph on the disease by Rudolph (1931) lists the known host range up to 1931. Engelhard (1957) published a host index for *V. albo-atrum* that included both herbaceous and woody plants.

NEWLY IDENTIFIED HOSTS

Routine isolations have been made at the Illinois Natural History Survey from branch samples of diseased trees and shrubs since 1926. During the last 42 years *V. albo-atrum* (including *V. dahliae* Kleb.) has been obtained from several hosts growing in widely scattered areas of the state. Table 1 shows the woody hosts reported for Illinois by 1956, including 30 tree and shrub species and varieties (Carter 1938, 1940, 1945; Engelhard & Carter 1956). Since the last of these reports was published, 26 additional species and varieties of woody ornamentals, also listed in Table 1, have been identified as hosts in Illinois. Twenty-two of the plant species or varieties, identified at the Illinois Natural History Survey and listed in Table 1, are believed to be previously unrecorded hosts in the United States, as no records of these hosts were found. However, at least 3 of these 22 hosts have been reported in other countries. A few of the new Verticillium hosts reported here have been mentioned in reports which were primarily field survey reports. Where there is no indication that the fungus was isolated from infected wood and positively identified, the field report usually is not cited.

PATHOGENICITY TESTS

Since 1957 *Verticillium* isolates from various hosts have been tested at the Illinois Natural History Survey for pathogenicity to the respective host plant. Most of the trees and shrubs were available in our research arboretum. Occasionally certain species were not available and had to be purchased as seedlings. These seedlings were established in pots in our greenhouse.

Pathogenicity was tested by inoculating 5–20 plants of each species or variety, and an equal number of uninoculated plants was used as a control for each species. Each plant was inoculated by placing a drop of spore suspension in a chisel wound made in the base of the trunk. An attempt was made to reisolate the fungus within 7 days following the initial appearance of foliage symptoms. External symptoms were produced 2 weeks to 3 months after inoculation on all species except silver maple. Silver maple did not produce typical foliage symptoms, but did have scattered faint green streaks in the twigs 4–5 feet from the point of inoculation. The fungus was recovered from the discolored area 2 months after inoculation.

Pathogenicity was established for 18 of the 22 plant species listed in Table 1 as new hosts in the United States. Pathogenicity was established for an additional four plant species that were newly discovered hosts in Illinois and for an additional eight species from which *V. albo-atrum* had been isolated but for which proof of pathogenicity had not been established.

HOSTS OUTSIDE OF ILLINOIS

Table 2 lists the Verticillium tree and shrub hosts identified in addition to the 1957 list of Engelhard and those listed for Illinois in Table 1. Most of these hosts have been reported since 1957. Engelhard's list and Tables 1 and 2 include most of the world's known Verticillium wilt hosts among trees and shrubs.

VERTICILLIUM WILT SYMPTOMS

Some tree and shrub species tend first to show foliage symptoms during a limited period of the growing season; other species have symptoms appearing at any time throughout the growing season. The times when plant growth begins and ceases are variable in Illinois, since the state has three climatic zones (Rehder 1940:ii,xii). In Illinois, Verticillium wilt appears to be most prevalent in trees and shrubs in the area that demarks the line between climatic zones IV and V and appears progressively less prevalent on both sides of this imaginary line. Both temperature and moisture may be factors that contribute to the

TABLE 1.—Tree and shrub hosts of *Verticillium albo-atrum* in Illinois.

Host Plant	*Verticillium* Isolations for Illinois, 1926-1968			Pathogenicity Tests		Reported as a Host	
	First Year Isolated in Illinois	Number of Years Isolated	Number of Naturally Infected Plants	Number of Plants Inoculated	Number of Plants Infected	United States	Other Countries
Almond (*Prunus amygdalus* Batsch.)	1932	1	1			Ill. (Carter 1938)	
Ash spp. (*Fraxinus* spp.)	1957	8	10				
Black (*F. nigra* Marsh.)	1962	1	1			This report	
Blue (*F. quadrangulata* Michx.)	1957	3	3	20[a]	14	This report	
European (*F. excelsior* L.)	1964			10[b]	6	This report	
Green (*F. pennsylvanica* Marshall var. *subintegerrima* (Vahl) Fernald)	1957	3	4	20[a]	7	Colo. (Thomas 1950)	
White (*F. americana* L.)	1959	3	3	20[a]	15	This report	
Azalea (*Rhododendron molle* G. Don)	1964	1	1	10[a]	3	This report	
Barberry spp. (*Berberis* spp.)	1957	2	2				
Japanese (*B. thunbergii* DC.)	1933	5	6	10[a]	3	Mass. (Boyd 1930) Ill. (Carter 1945) N.J. (White 1936)	
Boxwood, Korean (*Buxus microphylla koreana* Nakai)	1960	1	1	5[a]	1	This report	
Catalpa spp. (*Catalpa* spp.)	1942	6	8				
Western (*C. speciosa* Warder)	1936	3	4			Ill. (Carter 1938) Kans. (Rogerson 1957)	
Coffee tree, Kentucky (*Gymnocladus dioica* (L.) K. Koch.)	1966			20[b]	6	This report	
Cork tree (*Phellodendron amurense* Rupr.)	1964			5[b]	2	This report	
Elm, American (*Ulmus americana* L.)	1931	28	406	10[a]	4	Ill. (Carter 1938), widespread (Kelsheimer & May 1940)	Canada (Quebec 1961)
var. Augustine Ascending	1955	1	1			Ill. (Engelhard & Carter 1956)	
Henry Field	1960	1	1			This report	
Littleford	1939	1	4			Ill. (Carter 1940)	
Moline	1939	3	5			Ill. (Carter 1940), Kans. (Rogerson 1957)	
Chinese (*U. parvifolia* Jacq.)	1951	1	1			Ill. (Engelhard & Carter 1956)	
English (*U. procera* Salisb.)	1955	1	1			Ill. (Engelhard & Carter 1956), widespread (Kelsheimer & May 1940)	
Slippery (*U. rubra* Muhl.)	1951	2	7			Ill. (Engelhard & Carter 1956), widespread (Kelsheimer & May 1940)	
Goldenrain tree (*Koelreuteria paniculata* Laxm.)	1948	2	3	5[a]	3	Ill. (Engelhard & Carter 1956)	
Linden, American (*Tilia americana* L.)	1939	4	4	20[a]	12	Ill. (Carter 1940)	
Little leaf (*T. cordata* Mill.)	1964			20[b]	11	This report	
Locust, Black (*Robinia pseudoacacia* L.)	1932	2	2			Ill. (Carter 1938)	Italy (Goidanich 1935)
Magnolia spp. (*Magnolia* spp.)	1951	3	3			Ill. (Engelhard & Carter 1956)	
Saucer (*M. soulangeana* Soul.)	1959	3	3	5[a]	5	Ind. (Schreiber *et al.* 1961)	
Star (*M. stellata* (Sieb. & Zucc.) Maxim.)	1963	1	1	5[a]	2	This report	
Maple spp. (*Acer* spp.)	1947	9	24			Calif. (Baker *et al.* 1940)	
Amur (*A. ginnala* Maxim.)	1958	1	1	10[a]	5	This report	
Black (*A. nigrum* Michx. f.)	1936	1	1			Ill. (Carter 1938)	

TABLE 1.—Continued

Host Plant	*Verticillium* Isolations for Illinois, 1926-1968			Pathogenicity Tests		Reported as a Host	
	First Year Isolated in Illinois	Number of Years Isolated	Number of Naturally Infected Plants	Number of Plants Inoculated	Number of Plants Infected	United States	Other Countries
Norway (*A. platanoides* L.)	1935	17	26	10[a]	3	N.C. & Va. (Hepting & Toole 1950), Ill. (Carter 1938), NW states (Bedwell & Childs 1938), Ore. (Martin 1929)	Italy (Goidanich 1934)
var. Crimson King	1960	1	1			This report	
var. schwedleri Nichols.	1937	5	6			Ill. (Carter 1938)	Holland (van der Meer 1926)
Red (*A. rubrum* L.)	1933	4	4			Ill. (Carter 1938)	Canada (Quebec 1961)
Sugar (*A. saccharum* Marsh.)	1926	22	50	20[b]	11	N.C. (Hepting & Toole 1950), Mass. (Martin 1926), Ill. (Carter 1938), N.Y. (Rankin 1914)	Canada (Quebec 1961)
Hedge (*A. campestre* L.)	1964			5[b]	4	This report	
Silver (*A. saccharinum* L.)	1964			5[c]	2	This report	
ak, Pin (*Quercus palustris* Muenchh.)	1960	1	1	15[a]	7	This report	
Red (*Q. rubra* L.)	1960			15[b]	4	This report	
agoda tree (*Sophora japonica* L.)	1964			5[b]	3	This report	Italy (Goidanich 1935)
rivet, Amur (*Ligustrum amurense* Carr.)	1943	3	3			Ill. (Carter 1945)	
ersimmon (*Diospyros virginiana* L.)	1940[d]	1	1			Ill. (Carter 1945)	
edbud (*Cercis canadensis* L.)	1941	9	18	10[a]	6	Kans. (Rogerson 1957), Ill. (Carter 1945)	
ose, Multiflora (*Rosa multiflora* Thunb.)	1947	1	1			Ill. (Engelhard & Carter 1956)	
ose daphne (*Daphne cneorum* L.)	1966	1	1	5[b]	2	This report	
ussian olive (*Elaeagnus angustifolia* L.)	1956	4	9	25[a]	16	Kans. (Rogerson 1957), N. Mex. (Smith 1960)	
assafras (*Sassafras albidum* (Nutt.) Nees.)	1940[d]	1	1			Ill. (Carter 1945)	
moke tree (*Cotinus coggygria* Scop.)	1936	11	12			Ohio (Ellett 1957), Ill. (Carter 1938), R.I. (Caroselli 1961)	Europe (Rudolph 1931)
our gum (*Nyssa sylvatica* Marsh.)	1955	2	2			Ill. (Engelhard & Carter 1956)	
umac, Fragrant (*Rhus aromatica* Ait.)	1943	2	2	5[b]	5	This report	
Smooth (*R. glabra* L.)	1936	6	9			Ill. (Carter 1938)	Europe (Rudolph 1931), England (Rudolph 1931)
Staghorn (*R. typhina* L.)	1960	2	2			This report	
ulip tree (*Liriodendron tulipifera* L.)	1949	8	18	20[b]	8	Conn. (Waterman 1956), Ill. (Engelhard & Carter 1956), W. Va. (Kessler & True 1960)	
iburnum spp. (*Viburnum* spp.)	1941	4	5				
Wayfaring tree (*V. lantana* L.)	1937	3	3			Ill. (Carter 1938), Ind. (Baines 1945)	
Doublefile (*V. tomentosum* Thunb.)	1964	1	1	5[a]	1	Ind. (Baines 1945)	
(*V. burkwoodii* Burkwood)	1964	1	1	5[b]	5	This report	
illowwood (*Cladrastis lutea* (Michx.) K. Koch.)	1938	3	3			Ill. (Carter 1940)	

[a] Pathogenicity was proved by inoculation of the isolated strain into the respective plant species, development of typical wilt symptoms, and reisolation of the fungus.

[b] Susceptibility was proved by inoculation with inoculum containing at least four different host isolates of *V. albo-atrum*, production of typical wilt symptoms, and reisolation of the fungus.

[c] Inoculated with a strain of *V. albo-atrum* from the sugar maple. The fungus was reisolated 2 months later from twigs having faint green streaks. leaf symptoms were observed.

[d] *Verticillium* spp. isolated. The fungus was not characteristic of *V. albo-atrum*.

variability in the prevalence of the disease, along with the presence of a large number of tree species growing in this area. Because of the loss of elms, a greater variety of tree species is being planted than previously.

Our plant disease clinic records indicate that 34 percent of the confirmed *V. albo-atrum* isolations occurred in the month of July, 20 percent in June, 20 percent in August, 10 percent in September, 8 percent in May, 6 percent in October, and only 2 percent in March, April, and November.

For the past several years observations have been made of Verticillium wilt symptoms on various tree species (Table 3). Variation in symptom expression and in extent and speed of decline often occurs among the different species. For simplification, the table includes the more commonly observed symptoms for each of the host species listed.

SUSCEPTIBILITY OF HOSTS

A summary of our laboratory records for the past 42 years indicates that nine tree and three shrub genera are most commonly affected by Verticillium wilt. *V. albo-atrum* was recovered most frequently from branch specimens of ash, barberry, catalpa, elm, magnolia, maple, redbud, Russian olive, smoke tree, sumac, tulip tree, and viburnum.

In recent years strains of *V. albo-atrum* have been isolated that are quite virulent to numerous tree and shrub species. One strain isolated from a naturally infected pin oak tree (*Quercus palustris* Muenchh.) and inoculated into both pin oak and red oak (*Q. rubra* L.) produced wilt symptoms and internal discoloration similar to those of the oak wilt disease. The pin oak strain appears to be more virulent than maple strains in maple, ash, magnolia, and Russian olive. However, inoculation tests indicated that the pin oak strain was not pathogenic on white oak (*Q. alba* L.) or bur oak (*Q. macrocarpa* Michx.). In addition, a strain isolated from ash and inoculated into vigorous, growing trees, such as maple, redbud, and tulip tree, did not produce wilt symptoms. However, when this strain was placed in Russian olive, typical wilt symptoms were produced in 2–3 weeks.

Trees susceptible to Verticillium wilt occasionally show symptoms of this disease while they are still in a weakened condition following transplanting. Since there is evidence that *V. albo-atrum* isolates differ in

TABLE 2.—Tree and shrub hosts of *Verticillium albo-atrum* outside of Illinois.

Host Plant	Reported as a Host	
	United States	Other Countries
Apricot (*Prunus armeniaca* L.)	Widespread (Parker 1959)	Canada (Quebec 1961)
Azalea (*Rhododendron* spp.)	Mass. (Edson & Wood 1936)	
Boxwood (*Buxus* spp.)	Eastern U.S. (Hutchinson 1931)[a]	
(*B. sempervirens* L.)	Va. (Harrar 1937)	
Cherry (*Prunus avium* L.)	Widespread (Parker 1959)	Canada (Quebec 1961)
(*P. cerasus* L.)	Widespread (Parker 1959)	Canada (Quebec 1961)
Chestnut, Spanish (*Castanea sativa* Mill.)	Calif. (McCain 1963)	
Dogwood (*Cornus florida* L.)	Mass. (Holmes 1957)	
Elm, Scotch (*Ulmus campestris* L.)		Italy (Goidanich 1935), Holland (van der Meer 1926)
Holly olive (*Osmanthus ilicifolius* (Hassk.) Mouillef.)	Va. (Gruenhagen & Fordyce 1963)	
Horse chestnut (*Aesculus hippocastanum* L.)	Pa. (Armstrong 1941)	
Judas-tree (*Cercis siliquastrum* L.)		Italy (Goidanich 1935)
Magnolia (*Magnolia grandiflora* L.)	Calif. (McCain 1963)	
Maple, Japanese (*Acer palmatum* Thunb.)	N.Y. (Martin 1926)	
Oregon (*A. macrophyllum* Pursh.)	NW states (Bedwell & Childs 1938), Calif. (Mielke 1935)	
Painted (*A. mono* Maxim.)	Tenn. (Felix 1955)	
Striped (*A. pennsylvanicum* L.)	N.Y. (Hibben 1959)	
Sycamore (*A. pseudoplatanus* L.)		Canada (Quebec 1961), Italy (Goidanich 1934)
Oak spp. (*Quercus* spp.)		Russia (Krangauz 1958)
Turkey (*Q. cerris* L.)		Hungary (Georgescu *et al.* 1959)
Osage orange (*Maclura pomifera* (Raf.) Schneid.)	Conn. (Waterman 1941)	Italy (Goidanich 1934)
Peach (*Prunus persica* (L.) Batsch.)	Widespread (Parker 1959)	Canada (Quebec 1961)
Peony (*Paeonia* spp.)	Kans. (Martin 1926; Rogerson 1957)	
Plum (*Prunus domestica* L.)	Widespread (Parker 1959)	Canada (Quebec 1961)
Canada (*P. nigra* Ait.)		Canada (Quebec 1961)
Rose (*Rosa* spp.)		Canada (Quebec 1961)
Tree of heaven (*Ailanthus altissima* (Mill.) Swingle)		Italy (Goidanich 1935)

[a] *Verticillium* sp. isolated.

irulence to various hosts, the transporting of infected rnamental plants from one area to another may ccount for the appearance of the disease in tree and hrub species not previously attacked by it. It seems likely that the continued indiscriminate movement of nursery stock from one region to another will eventually bring about a complete distribution of all virulent strains to areas where they did not exist before.

TABLE 3.—Symptoms of *Verticillium* wilt observed on trees and shrubs.

Host Plant	Type of Decline	Leaf Symptoms	Vascular Symptoms in Xylem
Ash	Twig or branch dieback. Young trees usually appear to recover.	Abscission when still green; yellowing and scorching of other leaves	Faint tan streaks (when they occur); seldom found in twigs.
Azalea	Usually rapid decline, 2-4 weeks. Shrubs usually die.	Yellowing and browning	Yellowish-brown to brownish-black streaks
Boxwood	Twig dieback. Some plants may recover.	Browning and defoliation	Brown discoloration
Catalpa	Twig or branch dieback; occasionally branches or whole tree wilts. Trees appear to recover.	Yellowing and scorching	Purplish-pink to bluish-brown upon drying
Coffee tree	Twig dieback. Young seedlings recover.	Yellowing, scorching, and defoliation	Light brown streaks
Cork tree	Branch wilt. Young trees appear to recover.	Yellowing and defoliation	Faint brown streaks
Elm	Twig dieback. Sometimes whole tree dies.	Flaccidity, yellowing, and defoliation	Brown streaks
Goldenrain tree	Usually rapid decline, 2-4 weeks. Young trees may recover.	Scorching and browning	Brown streaks
Linden	Usually branch dieback. Some trees may recover.	Yellowing and browning	Brown streaks
Locust, black	Twig dieback.	Yellowing, browning, and defoliation	Light to dark reddish-brown streaks
Magnolia	Usually rapid decline; sometimes only branches are affected.	Yellowing, browning, and defoliation	Greenish-brown streaks
Maple	Varies with species from rapid to no decline. Symptoms may disappear and reappear years later.	Scorching, browning, and defoliation	Light to dark green streaks; often difficult to find.
Oak	Twig dieback, slow decline	Flaccidity, discoloring, browning, and some defoliation; similar to oak wilt.	Brown streaks and sometimes bands; similar to condition caused by oak wilt.
Pagoda tree	Slow decline, 1-2 years.	Yellowing and browning	No discoloration observed.
Redbud	Usually rapid decline, 2-4 weeks. Trees usually die.	Flaccidity, yellowing, browning, and some defoliation	Brown streaks
Rose daphne	Slow decline over 2-3 years.	Yellowing and defoliation	Brown streaks
Russian olive	Twig dieback; may occur each year or skip a year or two and reappear. Some trees may die.	Yellowing and browning	Brown streaks
Smoke tree	Rapid decline. Trees usually die.	Margins reddish-purple; later yellowing, browning, and defoliation.	Yellowish-brown to brownish-black streaks
Sour gum	Usually rapid decline, 2-4 weeks. Trees usually die.	Scorching and browning	Chocolate brown streaks
Sumac	Rapid decline, 2-4 weeks. Shrubs usually die.	Yellowing and browning	Light green streaks
Tulip tree	Rapid decline, 2-4 weeks. Trees usually die.	Yellowing and defoliation	Greenish-brown streaks. Bark may be killed in strips on trunk.
Viburnum	Rapid decline, 2-4 weeks. Shrubs usually die.	Browning and defoliation	Light to dark reddish-brown streaks
Yellowwood	Rapid decline, 2-4 weeks. Trees usually live.	Browning and defoliation	Brown streaks

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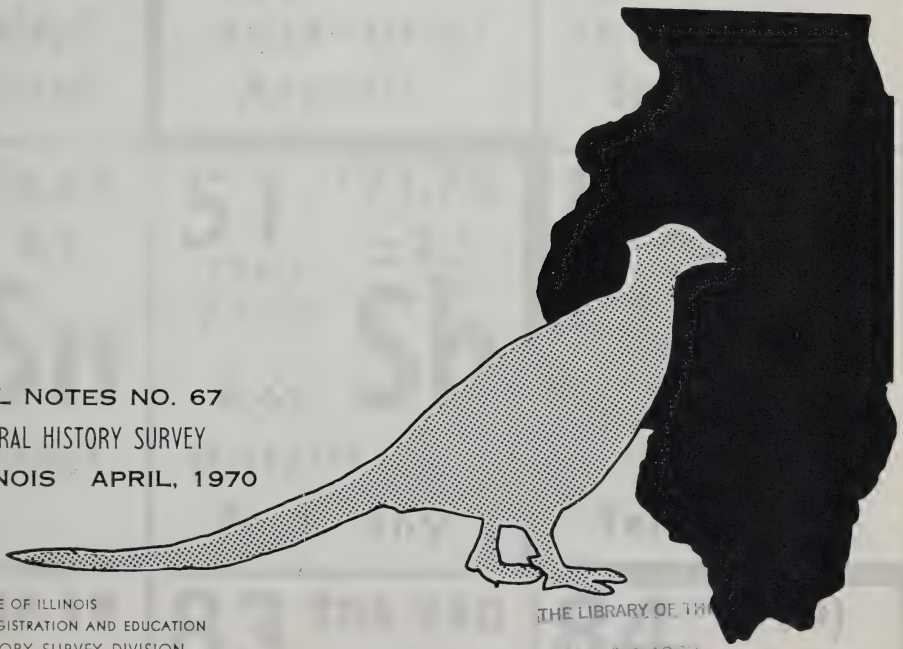
Concentrations of Chemical Elements in PHEASANT TISSUES

William L. Anderson

Peggy L. Stewart



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Concentrations of Chemical Elements in Pheasant Tissues

William L. Anderson and Peggy L. Stewart

The elemental constituents of biological material are of vital concern to many disciplines of research, particularly physiology, nutrition, and medicine. It is common knowledge that certain inorganic ions must be available for plants and animals to grow, survive, and reproduce. Conversely, many ions are toxic when present in excess — an axiom of primary concern to researchers in environmental pollution. The advent of the Atomic Age, and the realization that all elements can be made radioactive, magnified the importance of ions in living material, especially in man.

Chemical elements that occur in living material are commonly divided into two groups, major elements and trace elements, the line of demarcation being somewhat arbitrarily set at 0.01 percent of an organism (Schroeder 1965:217), or at roughly 5,000–10,000 ppm in tissue ash. However, as Schroeder points out, this distinction is not always applicable when high concentrations of trace elements occur in special cases. Some trace elements — those having a physiological function for at least one organism — are known to be essential, while others — those for which no function has yet been discovered — are "nonessential." Many of the "nonessential" ions accumulate in living organisms as the organisms increase in age, a phenomenon that has recently been associated with certain diseases in man (Schroeder 1965:225-226).

This paper reports the concentrations of five major elements and 18 trace elements in selected body parts (blood, bones, fat, feathers, muscles, and internal organs) of 54 hen pheasants (*Phasianus colchicus*) collected from three areas in Illinois. The analyses were conducted during an investigation of the possible effects of inorganic ions on the distribution and abundance of pheasants in this midwestern state. Portions of the analyses, as well as analyses of soil, grit, and corn, have been published elsewhere under the title "Relationships between Inorganic Ions and the Distribution of Pheasants in Illinois" (Anderson & Stewart 1969). Because of their potential contribution to many areas of research, the analyses of the pheasants' body parts are presented in their entirety in this publication. So that comparisons of data may be made easily, all tables follow the Literature Cited section.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. William L. Anderson is an Associate Wildlife Specialist, Section of Wildlife Research, at the Illinois Natural History Survey, Urbana, and Peggy L. Stewart is a Research Associate at the Department of Physics, University of Tennessee, Knoxville.

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METHODS

Pheasants used in this study were collected by night-lighting (Labisky 1968*b*) from three areas — good pheasant range, fair range, and poor range — in Illinois (Table 1). The birds were of three age groups: 4-month-old juveniles, 7-month-old juveniles, and adults (Table 1). Juveniles were separated from adults by bursal examination. The 4-month-old juveniles were further aged to the nearest week according to advancement of molt of the primary flight feathers (Labisky 1968*a*:465).

After being held overnight in a wooden crate, the pheasants were weighed, then sacrificed by decapitation. Samples of whole blood were collected at the time of sacrifice and saved for analysis. To obtain an indication of size, the wing length of each bird was recorded. This measurement was taken as the distance from the anterior edge of the wrist joint of the wing to the tip of the longest primary feather after the curve of this feather had been flattened out along a ruler (Baldwin, et al. 1931:77–78). The pheasants were then placed individually in polyethylene bags, frozen, and held for 2–4 months until they could be dissected.

Bony tissues that were analyzed were the right foot, bones of the right leg (femur, fibula, and tibiotarsus), skull (including beak), and sternum. Skeletal muscles utilized were those of the right leg (all muscles attached to the femur, fibula, and tibiotarsus) and the larger muscles of the right half of the sternum (*pectoralis thoracica, supracoracoideus*–ventral head, and *coracobrachialis posterior*, see Hudson & Lanzillotti 1964: 3–15, for detailed descriptions). A sample of fat was obtained from deposits around the neck, on the posteroventral surface of the sternal muscles, and in the viscera. Organs excised were the adrenals, brain, bursa (from juveniles only), gizzard (muscular portion and lining were separated), heart, intestine (including colon and ceca), kidneys, liver, lungs, pancreas, spleen, reproductive organs (ovary and oviduct), thyroids, and thymuses. Samples of feathers were obtained by clipping the larger feathers, mainly the primaries and secondaries, from both wings.

After being excised, the body parts were carefully freed of all extraneous material and rinsed, if necessary, in doubly distilled water (ion concentration < 5 ppm). They were then rolled on a paper towel to remove excess moisture and blood. The heart and liver were opened to remove clots of blood, and the gall bladder was removed from the liver. After most of the contents were stripped from the intestine, ceca, and colon, these organs were opened and thoroughly rinsed. Bony tissues and feathers were dried in an oven (65° C.) until successive weighings indicated they had stopped losing weight. The other body parts were weighed immediately after being excised and cleansed. All body parts were placed in polyethylene bags or vials and stored in a freezer.

Analyses of the body parts were conducted in the Spectrographic Laboratory, Department of Physics, University of Tennessee, Knoxville. The samples were shawed, then pooled according to body part, geographical region, and, when the samples were large enough, age of the birds. (The smaller body parts — all internal organs except gizzard muscles, intestines, and livers—were pooled at the time they were extracted from the birds. Leg muscles and sternal muscles were pooled on a weight basis after they had been reduced to ash.) Pooling was necessary because (1) many of the body parts were too small to be adequately analyzed individually, and (2) the cost, in time and funds, of analyzing each body part of each bird was prohibitive.

All samples were weighed immediately before ashing procedures began. The resulting weights, which seldom differed more than 3 percent from the ones recorded at the time the birds were dissected, served as a check on the accuracy of the wet (or dry) weights of the tissues.

The samples were exposed to temperatures of increasing intensity, then ashed in a muffle furnace at 550° C. for 12–72 hours, the length of time depending on the nature of the body part. Early phases of the ashing procedure were accelerated by adding distilled concentrated sulfuric acid to the samples. Concentrations of major elements in the ash were determined by flame photometric (calcium, magnesium, potassium, and sodium) and colorimetric (phosphorus) procedures. Analyses for trace elements were accomplished by atomic absorption (zinc) and emission spectrography (aluminum, barium, boron, cobalt, chromium, copper, iron, lead, manganese, molybdenum, nickel, silver, strontium, tin, titanium, vanadium, and zirconium). The ashing and analytical procedures were based on techniques developed by Peggy L. Stewart and Isabel H. Tipton (unpublished data) for analyzing human food (used for fat, feathers, muscles, and internal organs), feces (used for bones and feet), and urine (used for blood).

Care was taken throughout all phases of the dissecting, ashing, and analytical procedures to prevent contamination of the samples. Dissecting instruments were thoroughly washed and then rinsed in doubly distilled water before opening each bird; new scalpel blades were also used with each bird. Except when the dissecting instruments were used, the body parts were never allowed to touch metal. The samples were always stored in polyethylene containers, and fused silica dishes that had highly glazed surfaces were used to hold the samples during ashing procedures.

FINDINGS AND DISCUSSION

Validity of the Data

It should be emphasized that, as already mentioned, the analyses were conducted on pooled samples; the larger tissues were pooled according to geographical region and age of the birds, the smaller ones by region only. While this procedure has obvious limitations, the values obtained can be accepted with reasonable confidence. Theoretically, the concentrations of elements obtained for the pooled samples should approximate mean concentrations one would get if the tissues were analyzed individually. The consistency of many of the concentrations in comparable body parts—among birds of the three age groups and from the three regions — adds further confidence to the validity of the data (see tables).

However, a word of caution is in order. In biological material, mean concentrations of chemical elements, as well as means of percent ash of wet (or dry) weights, may be skewed toward high values (Tipton, et al. 1963:97). For this reason, Tipton, et al. (1963:100)

consider the median concentration to be a more appropriate measure of central tendency than the mean. This was true for at least some of the values for the pheasant tissues; for instance, concentrations of copper in the pooled samples of feet had a median value of <5 ppm, whereas the mean was an unrealistic >46 ppm (Table 13). In the following discussion, median concentrations in comparable body parts — among birds of the three age groups and from the three regions — are used in most instances. This, of course, does not overcome the possibility that concentrations in individual pooled samples may in themselves be skewed toward high values.

Size and Weight of the Pheasants

Mean wing lengths and body weights indicated that pheasants from the three areas were of similar size and were in the same general physical condition (Table 1). The only exceptions were the two adults from Neoga, which were larger and heavier, on the average, than adults from Sibley and Humboldt. In general, and regardless of the area from which they were collected, adults were larger and heavier than juveniles.

Percent Ash of the Wet (or Dry) Tissues

Weights of the ash of the pheasants' body parts are presented in grams and as percentages of the wet (or dry) weights in Table 2. Percent ash of the dry weight of bones had a median value of 62.86. Feet, which comprise considerable keratinous and other tissue as well as bone, contained less ash, the median value being 37.82 percent on a dry-weight basis. Spector (1956:73), after compiling the work of many researchers, reported the ash content of dry, fat-free bone from several species of vertebrates to be roughly 61–75 percent; the ash content of femurs from turkeys was approximately 70 percent. Thus, the percent ash of pheasant bones appears to be similar to percentages for bones of many other vertebrates.

Dried feathers from the pheasants contained a median of 1.29 percent ash (Table 2). The ash content of feathers is apparently greater than that of hair, which is also a keratinous appendage of the skin. Human hair has been reported to be 0.2–0.9 percent ash on a dry-weight, fat-free basis (Spector 1956:77).

Median concentrations of ash in whole blood and in soft body parts of the pheasants were seldom less than 1 percent, and never more than 2 percent, on a wet-weight basis (Table 2). The only exceptions were fat (median 0.28 percent), intestines (median 0.63 percent), and thyroid glands (median 0.41 percent). Pancreases and thymuses contained the highest concentrations of ash, the median values being 1.77 and 1.93, respectively. It is of special interest that the concentrations of ash in all internal organs except livers and bursae were greater for birds from Sibley — good pheasant range — than for birds from Neoga — poor range (Table 2). This finding is elaborated upon elsewhere (Anderson & Stewart 1969:262, 268).

The median values for percent ash of soft tissues of pheasants were, in general, similar to those for humans (Tipton & Cook 1963:105–130). Notable exceptions were concentrations of ash in adrenal and thyroid glands, which were 1½ times greater and 63 percent less, respectively, in pheasants than in humans.

Concentrations of Elements in Tissues

Concentrations of the 23 elements in the various body parts are summarized in Tables 3–25. The concentrations are given in grams per 100 grams of ash (percentage in ash) for major elements and in micrograms per gram of ash (ppm in ash) for trace elements. To convert from ppm to percent, move the decimal four digits to the left. Values preceded by < or > indicate the concentrations were beyond the analytical capabilities of the techniques used; the values given are the lower or upper limits of detection attained.

Concentrations in the ash may be converted to a wet-weight (or dry-weight) basis with this calculation: concentration in ash × percent ash of wet (or dry) body part ÷ 100. If concentrations in dry tissue are desired for those tissues for which the percent ash is presented on a wet-weight basis (Table 2), percent ash of wet tissue can be converted to a dry-weight basis with the aid of data presented in the literature. It is suggested that percent ash of wet and of dry human tissues published by Tipton & Cook (1963:105–130) be used for such conversions.

Of the elements for which analyses were conducted, phosphorus was found to be the most abundant in the pheasants, the median concentrations in ash being more than 12 percent in all samples analyzed for this element except those of blood, fat, and feathers. Potassium, with median values exceeding 12 percent in blood and in most soft body parts, was also present in abundance. Calcium was highly abundant in bone, the median concentration being 34.13 percent, and moderately abundant in thyroid glands, in which the median concentration was 5.26 percent. Of the other two major elements, magnesium was most abundant in thyroid glands (median 8.42 percent) and sodium was most abundant in blood (median 16.88 percent). High concentrations (median 14.21 percent) of sodium also occurred in the thyroids. It is interesting that the ash of thyroid glands contained the highest concentrations for magnesium and the second highest for calcium, potassium, and sodium. Concentrations of phosphorus were not determined for these glands.

The highest median concentrations for nine of the trace elements occurred in the ash of gizzard linings (aluminum, 5,000 ppm; barium, 133; boron, 58; copper, 483; and titanium, 700) or of feathers (lead, 317 ppm; vanadium, >100; zinc, 28,125; and zirconium, 322). These body parts also contained the second or third highest median concentrations for six of the remaining elements. Of these, in the analyses conducted, iron and tin were most concentrated in the ash of lungs (>7,000 and 42 ppm, respectively), nickel and silver in fat (158 and 15, respectively), cobalt in bursae (106), manganese in livers (298), molybdenum in kidneys (124), and strontium in spleens (126). Chromium was extremely low in all tissues, the median values never exceeding 4 ppm. (Iron was probably more concentrated in blood than in lungs. Because of limitations of the analytical procedure used, actual concentrations of iron in blood were not determined.)

If the amounts of elements in ash are converted to concentrations in the wet body parts (dry for bones and feathers), bone, because of its high ash content, becomes the body part containing the highest concentrations of many elements. However, concentrations in unashed bone, as well as in feathers, were based on dry weights, while those in other unashed tissues were calculated on a wet-weight basis. Thus, concentrations in unashed bones and feathers are not strictly comparable to those in the wet tissues. If bone is excluded, concentrations of elements in wet (or dry) tissues exhibit patterns of distribution similar to, but in lesser quantities than, those in ash. Exceptions were concentrations in fat, intestines, and thyroid glands, where the percent ash was exceedingly low (Table 2). Consequently, these body parts contained relatively lower concentrations, when compared with those of other body parts, on a wet-weight basis than in ash.

A particularly interesting finding was the relatively greater abundance of inorganic ions in leg muscles than in sternal muscles. Calcium was 10 times greater, and six of the trace elements (aluminum, barium, cobalt, copper, vanadium, and zinc) at least 2 times greater in leg muscles. Only one element, titanium, was strikingly more abundant (5 times greater) in sternal muscles than in leg muscles.

The behavior of barium and strontium in the pheasants — their wide distribution and relatively uniform concentrations (Tables 9 and 20) — is similar to that of essential elements. Tipton & Cook (1963:142, 144) reported the same findings for humans, but added that this might be expected of strontium, which is chemically closely related to the essential element calcium. The high concentrations of barium and strontium in pheasants, as compared with those in humans, tempt speculation about the essentiality of these elements for birds. Schroeder (1965:218) has stated that strontium is essential or probably essential for mammals.

Changes in concentrations with increase in age of the pheasants were evident for several elements. Four of the major elements (calcium, magnesium, phosphorus, and sodium) were usually less abundant in the ash of intestines and livers of adults than in those of juveniles, perhaps because of higher metabolic rates in the younger birds. Concentrations of sodium also decreased in leg muscles and sternal muscles with increase in age. However, sodium became more concentrated in bones and feet as the birds became older. Other changes associated with increased age were increases in concentrations of aluminum in intestines, barium in bones, feet, intestines, and gizzard muscles, lead in bones and feet, strontium in intestines, and zirconium in bones. Of these five trace elements, only strontium is known to be essential or probably essential for mammals (Schroeder 1965:218). Schroeder (1965: 227) also reported that at least four of these elements, zirconium being the exception, accumulate in one or more tissues of humans with increasing age.

Comparisons With Concentrations in Other Vertebrates

In those body parts that were comparable, the median concentrations of elements in pheasants exhibited many similarities to median values reported for humans by Tipton & Cook (1963:105–130) and Tipton et al. (1965:410–439). Noteworthy exceptions were magnesium in thyroids (9 times greater in pheasants), potassium in pancreases (2 times greater), and calcium and potassium in hearts and kidneys (40–50 percent less).

Among essential trace elements (those essential or probably essential for mammals, Schroeder 1965:218), important differences between pheasants and humans were in cobalt in kidneys and muscles (10–20 times greater in pheasants); manganese in livers, pancreases, and spleens (2–3 times greater); molybdenum in kidneys (4 times greater) and in livers (60 percent less); and zinc in kidneys, lungs, muscles, and spleens (50–70 percent less). In most of the body parts analyzed, copper and iron were 20–70 percent less abundant in pheasants than in humans. As the pheasants were allowed to bleed when they were sacrificed, their body parts would understandably contain less iron than those of humans.

"Nonessential" elements exhibiting differences between pheasants and humans were aluminum in livers, muscles, and spleens (2–5 times greater in pheasants); nickel in brains, livers, pancreases, and spleens (2–4 times greater); silver in brains, muscles, and spleens

(30 times greater); and titanium in livers, muscles, and spleens (10 times greater). In most of the body parts that were comparable, barium and strontium were 2–20 times greater, and lead was 30–70 percent less in pheasants than in humans. It is interesting that of the "nonessential" elements showing differences between pheasants and humans, all except lead were more abundant in the birds. As pheasants ingest appreciable amounts of soil (Harper & Labisky 1964: 726), as well as grit, an accumulation of "nonessential" elements in these birds might be expected.

Spector (1956:70–77) has summarized analytical work performed on many species of vertebrates. Although mammals were the most common animals on which analyses were conducted, birds, reptiles, amphibians, and fish were also listed. Concentrations of nine elements (the five major elements, plus copper, iron, manganese, and zinc) in six internal organs (brains, hearts, kidneys, livers, lungs, and spleens), muscle, and bone could be used for generalized comparisons between pheasants and other vertebrates. (Spector (1956:70) points out that the values he presents are rough approximations which are not subject to conclusive interpretation.) For these elements and these tissues, concentrations in pheasants agreed exceedingly well with those listed for other backboned animals. General exceptions were calcium in hearts (30–80 percent less abundant in pheasants), potassium and sodium in kidneys (35–55 and 50–70 percent less, respectively), and phosphorus and zinc in livers (30–55 and 10–90 percent less, respectively).

The *median* concentrations of elements in pheasant blood exhibited several striking differences from *mean* concentrations in mammalian blood reported by Bowen (1966:81–82). Notable examples were phosphorus (3 times greater in pheasants); cadmium, cobalt, and manganese (10–50 times greater); and nickel, silver, vanadium, and zinc (94–99 percent less).

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* * *

All tables are presented on the following pages.

TABLES

TABLE 1. — Data for 54 hen pheasants from which body part were excised and analyzed for 23 chemical elements.

	Sibley, Ill.			Humboldt, Ill.		Neoga, Ill.		
	Oct. 1966	Jan. 1967		Jan. 1967		Oct. 1966	Jan. 1967	
Number of birds	9	6	8	8	6	9	6	2
Mean age (months)	4.0±0.8*	ca.7	>19†	ca.7	>19†	4.4±0.5*	ca.7	>19†
Mean wing length (mm)	220±2	221±4	226±3	223±2	226±3	221±1	222±2	230±5
Mean body weight (grams)	841±17	875±19	943±31	856±21	960±16	838±31	873±18	1,052±41
Location (county, latitude and longitude)	Ford and Livingston 40°35′N., 88°23′W.			Coles 39°36′N., 88°19′W.		Cumberland 39°19′N., 88°27′W.		
Abundance of pheasants‡	>100			1.1–10.0		0.1–1.0		

* Aged according to advancement of molt of the primary flight feathers (Labisky 1968*a*:465). Mean lengths of the 10th primary of October-collected juveniles from Sibley and Neoga were 84±17 and 118±8 mm, respectively.

† Pheasants more than 1 year old could be aged only as adults by the techniques employed. The youngest adults were approximately 19 months old.

‡ Pheasants observed per 100 miles of driving during April 1963 (Labisky & Anderson 1965:132).

TABLE 2. — Weights of ash, in grams (numerators) and as percentages of wet (or dry) weights (denominators), of pooled body parts of hen pheasants collected from three areas in Illinois. Percentages of dry weights are in parentheses.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Number of hens	9	6	8	8	6	9	6	2		23	14	17
Blood	1.8433	1.3325	1.8107	1.4813	0.9899	1.0942*	1.3996	0.5591	Adrenals	0.0210	0.0116	0.0097
	1.14	1.17	1.19	1.18	1.17	1.17	1.20	1.26		1.14	1.15	0.88
Bones, leg	37.86	17.75	33.58	33.09	19.43	34.63	18.71	7.51	Brains	1.1633	0.7442	0.7130
	(82.12)	(57.98)	(75.78)	(77.62)	(59.41)	(72.86)	(57.97)	(66.33)		1.59	1.53	1.25
Bones, skull	12.10	9.99	13.76	13.06	9.58	11.20	8.96	3.47	Bursae	0.1040	. . .	0.0787
	(57.62)	(62.99)	(59.90)	(60.23)	(59.20)	(58.74)	(61.09)	(60.94)		1.77		1.96
Bones, sternum	15.03	10.27	16.02	14.61	11.02	16.60	10.79	4.61	Gizzard linings	0.4345	0.2820	0.2744
	(62.43)	(62.72)	(67.57)	(67.36)	(65.96)	(66.97)	(67.03)	(71.33)		0.91	1.05	0.78
Fat	0.1826	0.1231	. . .	0.1212	. . .	0.0782	0.1184	0.0536	Hearts	1.1640	0.6546	0.7968
	0.47	0.29		0.27		0.59	0.26	0.21		1.40	1.22	1.29
Feathers	1.0883	0.8218	1.1774	1.0098	0.8245	1.0581	0.7518	0.3290	Kidneys	1.4670	0.6351	0.8922
	(1.45)	(1.48)	(1.28)	(1.04)	(1.29)	(1.28)	(1.34)	(1.28)		1.76	1.30	1.44
Feet	18.32	14.65	13.94	17.88	10.71	19.70	9.84	3.89	Lungs	1.0251	0.4627	0.7232
	(42.01)	(49.13)	(31.54)	(44.24)	(33.62)	(43.61)	(32.56)	(33.58)		1.36	0.97	1.28
Gizzard muscles	1.4249	0.8837	0.9977	0.9851	0.6826	1.2856	0.7996	0.2975	Reproductive organs	0.1088	0.0636	0.0556
	1.14	1.18	1.11	1.12	1.06	1.08	1.12	1.02		1.40	1.25	1.27
Intestines	0.5346	0.2861	0.4429	0.2930	0.2177	0.3383	0.2179	0.0959	Pancreases	0.5261	0.2669	0.3247
	0.66	0.65	0.72	0.54	0.61	0.50	0.58	0.64		1.94	1.75	1.77
Livers	1.9026	1.0578	1.3979	1.2740	1.0987	1.5059	1.0150	0.4355	Spleens	0.0811	0.0391	0.0618
	1.62	1.25	1.32	1.17	1.40	1.26	1.42	1.52		1.65	1.45	1.56
Muscles, leg	9.48*	7.03	9.48	8.34*	7.32	11.04	7.35	2.85	Thymuses	0.1588	. . .	0.1472
	1.52	1.53	1.52	1.57	1.52	1.53	1.53	1.59		1.99		1.86
Muscles, sternal	13.39	8.35*	11.18*	14.15	8.77*	12.83	10.88	3.73	Thyroids	0.0040	0.0013	0.0019
	1.44	1.47	1.32	1.49	1.38	1.34	1.46	1.26		0.54	0.29	0.41

* Sample consisted of body parts from one hen less than indicated above.

TABLE 3. — Grams of calcium per 100 grams of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	0.78	0.42	0.63	0.73	0.79	0.75	0.63	0.74	Adrenals	1.19	1.29	2.16
Bones, leg	35.50	33.00	30.00	36.75	37.00	27.25	29.00	33.75	Brains	1.10	0.70	0.75
Bones, skull	26.00	33.50	33.00	39.75	35.00	34.50	26.00	33.50	Bursae	0.10	...	0.03
Bones, sternum	33.00	36.00	37.00	35.50	23.00	34.50	36.50	35.50	Gizzard linings	2.10	4.10	1.50
Fat	0.25	0.25	...	...	...	0.65	0.50	...	Hearts	0.40	0.15	0.18
Feathers	5.00	3.75	5.25	3.75	4.25	5.00	6.00	7.00	Kidneys	0.40	0.35	0.35
Feet	34.00	27.00	37.00	36.75	36.00	31.25	37.25	35.00	Lungs	0.60	0.83	0.68
Gizzard muscles	1.05	0.53	0.65	0.43	0.53	0.43	0.50	0.65				
Intestines	1.25	0.78	0.90	0.93	...	1.65	1.03	1.00				
Livers	0.38	0.33	0.28	0.33	0.35	0.53	0.25	0.33	Pancreases	0.55	0.78	0.73
Muscles, leg	2.95	2.40	3.30	3.05	4.10	2.48	3.00	3.65				
Muscles, sternal	0.30	0.38	0.33	0.25	0.33	0.40	0.28	0.20	Thyroids	3.25	7.69	5.26

TABLE 4. — Grams of magnesium per 100 grams of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	0.53	0.45	0.52	0.56	0.55	0.54	0.50	0.36	Adrenals	0.88	0.86	1.75
Bones, leg	0.45	0.45	0.50	0.50	0.55	0.50	0.55	0.50	Brains	0.95	1.00	0.85
Bones, skull	0.60	0.50	0.45	0.70	0.55	0.65	0.55	0.65	Bursae	0.75	...	0.40
Bones, sternum	0.35	0.50	0.50	0.50	0.50	0.50	0.60	0.50	Gizzard linings	0.60	0.65	0.56
Fat	0.40	0.88	...	...	...	0.93	1.13	...	Hearts	1.00	1.50	1.15
Feathers	4.00	3.38	3.13	2.88	2.88	3.13	3.38	2.13	Kidneys	1.45	0.60	0.90
Feet	0.45	0.60	0.50	0.65	0.55	0.65	0.50	0.55	Lungs	0.95	0.95	1.05
Gizzard muscles	1.25	1.15	1.35	1.30	1.20	1.45	1.25	1.25				
Intestines	3.80	3.50	2.80	3.45	...	3.20	2.25	1.55				
Livers	1.15	1.35	0.80	1.05	1.40	1.05	0.65	0.80	Pancreases	1.80	1.75	1.90
Muscles, leg	1.25	1.25	1.30	1.30	1.15	1.35	1.35	1.30				
Muscles, sternal	1.95	1.60	1.60	2.30	1.95	1.90	1.40	1.65	Thyroids	3.75	13.08	8.42

TABLE 5. — Grams of phosphorus per 100 grams of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	10.42	9.92	10.83	10.09	10.98	10.12	9.32	6.19				
Bones, leg	13.75	13.00	11.38	13.38	15.50	12.88	13.38	12.38	Brains	17.25	19.88	19.63
Bones, skull	12.00	11.75	13.88	13.88	13.13	11.38	13.50	11.75				
Bones, sternum	13.38	14.13	12.75	13.50	13.50	13.75	13.00	16.38	Gizzard linings	15.13	24.38	...
Fat	3.40	...	...	...	...	...	...	...	Hearts	17.03	19.13	17.25
Feathers	4.40	3.30	5.20	2.80	3.55	3.95	4.80	4.00	Kidneys	14.00	18.50	17.88
Feet	14.38	12.63	14.13	12.63	12.63	11.63	14.50	13.13	Lungs	16.75	19.88	17.25
Gizzard muscles	14.63	16.25	15.50	16.00	18.38	14.13	14.13	13.38				
Intestines	30.12	...	20.63	24.38	...	22.50	18.25	18.25				
Livers	14.13	6.75	11.63	14.25	14.50	14.50	12.38	10.25	Pancreases	21.25	9.30	26.25
Muscles, leg	15.63	19.50	31.87	18.75	16.00	19.13	20.38	28.25				
Muscles, sternal	12.75	13.13	15.75	17.00	12.75	13.75	15.50	16.75				

TABLE 6. — Grams of potassium per 100 grams of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	13.75	12.92	15.21	14.25	12.80	12.71	14.58	13.04	Adrenals	14.95	18.53	26.91
Bones, leg	0.19	0.15	0.10	0.14	0.15	0.13	0.14	0.09	Brains	18.00	16.00	21.20
Bones, skull	0.27	0.30	0.24	0.16	0.17	0.20	0.18	0.30	Bursae	11.10	...	6.20
Bones, sternum	0.40	0.40	0.22	0.20	0.36	0.25	0.20	0.28	Gizzard linings	5.40	4.60	4.71
Fat	8.55	20.50	...	...	...	5.25	17.00	...	Hearts	15.50	17.50	12.30
Feathers	4.50	2.50	3.50	2.38	2.38	3.50	2.50	2.63	Kidneys	17.00	10.50	10.30
Feet	0.25	0.17	0.13	0.12	0.21	0.10	0.13	0.14	Lungs	17.90	14.50	18.50
Gizzard muscles	19.80	19.00	19.60	20.20	17.10	19.20	20.00	19.80				
Intestines	19.80	17.80	12.10	15.30	...	10.90	10.00	10.60				
Livers	15.30	16.70	15.80	14.50	15.50	15.30	11.90	17.75	Pancreases	32.20	32.20	31.60
Muscles, leg	16.50	17.00	17.70	16.20	16.00	17.70	16.20	16.80				
Muscles, sternal	21.00	16.90	16.60	31.40	17.00	20.00	14.00	19.50	Thyroids	21.89	35.00	26.84

TABLE 7. — Grams of sodium per 100 grams of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	19.58	16.67	17.08	17.11	15.85	19.77	16.49	16.39	Adrenals	6.81	9.96	13.76
Bones, leg	0.44	0.48	0.53	0.53	0.54	0.35	0.40	0.46	Brains	7.70	5.55	8.60
Bones, skull	0.51	0.56	0.79	0.47	0.74	0.47	0.53	0.62	Bursae	3.03	...	1.78
Bones, sternum	0.35	0.43	0.53	0.35	0.55	0.47	0.34	0.58	Gizzard linings	1.90	1.35	1.97
Fat	1.68	3.08	...	...	...	2.50	3.08	...	Hearts	5.10	6.00	4.50
Feathers	6.50	4.50	5.38	5.00	4.63	6.00	5.13	6.25	Kidneys	6.75	4.65	5.10
Feet	0.89	0.85	0.94	0.74	0.80	0.48	0.81	1.00	Lungs	6.25	6.05	7.15
Gizzard muscles	4.50	4.00	4.35	4.35	3.45	4.35	4.00	3.80				
Intestines	5.75	5.85	4.15	4.40	...	4.00	3.20	3.70				
Livers	4.65	4.65	4.20	5.15	4.70	8.80	2.70	4.65	Pancreases	4.00	2.35	4.25
Muscles, leg	3.30	2.85	3.05	2.90	2.75	3.50	2.70	3.20				
Muscles, sternal	2.85	1.65	1.60	2.50	1.95	2.75	1.50	2.00	Thyroids	14.00	23.08	14.21

TABLE 8. — Micrograms of aluminum per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	106	182	48	134	81	174	183	182				
Bones, leg	<45	<45	<45	<45	<45	<45	<45	<45	Brains	25	31	62
Bones, skull	<45	<45	<45	<45	<45	<45	<45	<45	Bursae	3,339	...	5,000
Bones, sternum	<45	<45	<45	<45	<45	<45	<45	<45	Gizzard linings	5,000	4,395	>8,600
Fat	770	1,012	...	341	...	409	413	626	Hearts	111	169	130
Feathers	5,000	6,096	5,000	2,519	5,000	5,000	5,000	5,000	Kidneys	116	188	141
Feet	198	1,011	<45	419	606	134	659	274	Lungs	2,622	1,926	912
Gizzard muscles	111	140	113	76	40	160	67	144	Reproductive organs	131	787	293
Intestines	149	595	193	327	712	50	112	492	Pancreases	136	95	251
Livers	306	604	195	383	248	198	309	212	Spleens	57	1,825	1,150
Muscles, leg	111	123	94	78	150	97	121	120	Thymuses	71	...	112
Muscles, sternal	55	41	42	64	53	70	54	41				

TABLE 9. — Micrograms of barium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	1.78	0.12	0.03	0.19	1.67	0.01	0.46	19.06				
Bones, leg	26	19	29	19	11	29	37	68	Brains	3	21	23
Bones, skull	19	21	49	30	32	54	48	81	Bursae	39	...	44
Bones, sternum	110	15	30	23	24	20	15	72	Gizzard linings	91	133	163
Fat	16	67	...	78	...	<0.5	48	165	Hearts	9	9	7
Feathers	169	174	158	92	173	87	62	54	Kidneys	4	14	8
Feet	29	29	44	26	45	37	56	107	Lungs	24	14	14
Gizzard muscles	7	46	54	41	43	28	57	67	Reproductive organs	104	47	112
Intestines	19	40	74	35	89	7	38	48	Pancreases	5	24	53
Livers	25	34	15	14	4	4	7	9	Spleens	11	132	38
Muscles, leg	<0.5	15	51	53	52	24	34	35	Thymuses	9	...	4
Muscles, sternal	16	11	11	30	17	35	16	21				

TABLE 10. — Micrograms of boron per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	9	22	23	34	8	8	13	5				
Bones, leg	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	Brains	5	7	3
Bones, skull	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	Bursae	39	..	18
Bones, sternum	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	Gizzard linings	55	58	59
Fat	7	69	..	28	..	32	72	225	Hearts	6	7	3
Feathers	81	30	22	33	42	138	33	52	Kidneys	5	4	4
Feet	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	Lungs	4	5	3
Gizzard muscles	6	7	5	4	6	13	8	5	Reproductive organs	12	80	43
Intestines	4	15	13	5	56	15	8	19	Pancreases	4	6	4
Livers	8	6	9	13	3	5	5	6	Spleens	15	29	10
Muscles, leg	4	2	10	3	4	1	2	4	Thymuses	6	..	4
Muscles, sternal	6	2	10	6	6	4	4	7				

TABLE 11. — Micrograms of chromium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	0.30	0.25	0.12	1.55	0.55	0.62	0.95	1.84				
Bones, leg	<4	<4	<4	<4	<4	<4	<4	<4	Brains	1.0	<0.5	1.0
Bones, skull	<4	<4	<4	<4	<4	<4	<4	<4	Bursae	<0.5	..	<0.5
Bones, sternum	<4	<4	<4	<4	<4	<4	<4	<4	Gizzard linings	1	1	1
Fat	<0.5	<0.5	..	<0.5	..	1.0	2.0	1.4	Hearts	1.0	<0.5	1.0
Feathers	1	2	2	2	2	3	2	2	Kidneys	1.0	<0.5	2.5
Feet	<4	<4	<4	<4	<4	<4	<4	15	Lungs	<0.5	1.0	<0.5
Gizzard muscles	<0.5	1.0	<0.5	<0.5	1.0	1.0	1.7	1.5	Reproductive organs	<0.5	1.2	<0.5
Intestines	1.0	<0.5	<0.5	1.0	1.0	<0.5	<0.5	1.2	Pancreases	<0.5	1.0	1.0
Livers	2	1	2	5	1	1	2	4	Spleens	<0.5	1.0	37.6
Muscles, leg	0.8	1.5	1.0	1.4	1.3	1.5	1.0	0.5	Thymuses	<0.5	..	1.0
Muscles, sternal	<0.5	<0.5	<0.5	0.5	1.0	0.5	0.5	1.0				

TABLE 12. — Micrograms of cobalt per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
lood	0.1	1.5	1.5	0.8	0.4	4.2	4.3	6.4				
ones, leg	<2.5	<2.5	4.0	10.0	<2.5	<2.5	4.0	<2.5	Brains	5	2	9
ones, skull	3.1	2.7	<2.5	4.6	3.1	<2.5	<2.5	3.1	Bursae	>120	..	91
ones, sternum	3.2	<2.5	<2.5	<2.5	<2.5	<2.5	2.7	<2.5	Gizzard linings	65	5	8
at	14	13	..	>120	..	37	17	>120	Hearts	3	2	6
eathers	111	15	76	26	>120	103	>120	>120	Kidneys	6	24	21
eet	17.6	<2.5	<2.5	<2.5	<2.5	4.9	<2.5	<2.5	Lungs	7	5	2
izzard muscles	31	5	79	9	3	47	1	98	Reproductive organs	1.9	<0.3	7.6
testines	54	81	12	20	>120	75	66	95	Pancreases	8	8	6
vers	5	18	27	22	25	4	7	3	Spleens	4.0	0.6	3.5
uscles, leg	38	6	73	>120	53	35	11	78	Thymuses	4	..	5
uscles, sternal	19	100	22	23	62	15	15	31				

TABLE 13. — Micrograms of copper per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
ood	46	37	31	59	32	34	42	28				
ones, leg	<5	<5	<5	<5	<5	<5	<5	<5	Brains	103	125	94
ones, skull	<5	<5	<5	<5	19	<5	<5	<5	Bursae	35	...	36
ones, sternum	<5	<5	<5	<5	<5	<5	<5	<5	Gizzard linings	483	128	>500
at	2	34	...	69	...	34	35	82	Hearts	170	184	149
eathers	127	116	131	131	140	135	130	137	Kidneys	126	98	168
eet	371	<5	<5	<5	<5	<5	<5	<5	Lungs	59	93	86
zzard Muscles	77	36	67	85	46	71	79	50	Reproductive organs	64	300	115
testines	68	148	121	112	178	126	121	77	Pancreases	129	128	109
vers	133	183	249	244	172	211	209	211	Spleens	105	131	295
uscles, leg	52	92	98	44	101	52	75	42	Thymuses	61	...	48
uscles, sternal	13	3	13	25	12	15	27	6				

TABLE 14. — Micrograms of iron per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
ood	>2,000	>2,000	>2,000	>2,000	>2,000	>2,000	>2,000	>2,000	Adrenals	2,619	5,172	36,842
nes, leg	<50	<50	<50	<50	<50	<50	<50	<50	Brains	1,250	2,436	1,969
nes, skull	51	<50	<50	<50	<50	<50	<50	<50	Bursae	2,030	...	1,400
nes, sternum	<50	<50	<50	<50	<50	<50	<50	<50	Gizzard linings	5,400	6,200	5,500
t	633	1,800	...	1,850	...	2,330	1,850	2,650	Hearts	3,900	3,319	4,284
athers	4,067	4,667	5,500	5,933	3,950	4,200	4,500	4,000	Kidneys	4,683	2,983	5,300
et	200	270	<50	131	109	<50	265	125	Lungs	>7,000	>7,000	>7,000
zzard muscles	1,900	2,380	2,380	2,950	2,690	1,770	2,560	3,680	Reproductive organs	5,600	6,367	3,517
estines	942	2,350	2,160	3,480	2,750	1,430	1,830	3,150	Pancreases	2,050	2,000	1,775
ers	4,000	3,750	5,000	5,250	7,500	5,750	3,750	1,000	Spleens	6,575	>7,000	5,400
scles, leg	1,001	619	2,647	1,417	1,941	733	1,194	1,165	Thymuses	1,919	...	2,350
scles, sternal	420	588	513	581	569	474	525	834				

TABLE 15. — Micrograms of lead per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	19	21	22	21	19	20	21	21				
Bones, leg	<0.5	31.0	28.9	<0.5	4.7	1.2	0.6	7.4	Brains	7	5	10
Bones, skull	1.5	<0.5	29.3	0.6	5.6	2.1	1.3	9.1	Bursae	22	...	2
Bones, sternum	<0.5	0.6	60.4	0.6	8.6	1.1	0.8	13.4	Gizzard linings	132	107	477
Fat	3	28	...	12	...	54	40	151	Hearts	2.9	4.6	<1.5
Feathers	168	266	500	62	358	500	478	276	Kidneys	6	17	19
Feet	0.5	0.6	51.3	0.6	7.0	1.5	1.8	6.6	Lungs	31	27	6
Gizzard muscles	43	20	44	31	29	9	6	38	Reproductive organs	116	76	47
Intestines	3	7	82	39	470	158	19	6	Pancreases	8	26	45
Livers	26	20	64	50	36	59	26	6	Spleens	120	58	36
Muscles, leg	72	12	14	7	41	13	18	15	Thymuses	13	...	9
Muscles, sternal	<1.5	<1.5	3.5	3.4	<1.5	5.7	3.4	5.7				

TABLE 16. — Micrograms of manganese per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	10	76	72	69	88	13	68	72				
Bones, leg	<8	<8	<8	<8	<8	<8	<8	<8	Brains	20	24	33
Bones, skull	<8	<8	<8	<8	<8	<8	<8	<8	Bursae	30	...	14
Bones, sternum	<8	<8	<8	<8	<8	<8	<8	<8	Gizzard linings	124	126	559
Fat	23	62	...	350	...	44	31	95	Hearts	21	37	24
Feathers	107	263	142	232	180	166	141	120	Kidneys	82	60	40
Feet	<8	<8	<8	<8	<8	<8	<8	<8	Lungs	25	41	21
Gizzard muscles	22	23	32	51	47	64	41	107	Reproductive organs	72	204	98
Intestines	100	136	131	184	348	70	229	100	Pancreases	126	277	189
Livers	436	138	281	315	271	605	492	150	Spleens	59	183	38
Muscles, leg	20	9	24	9	10	12	8	10	Thymuses	24	...	14
Muscles, sternal	10	<4	13	9	11	11	10	10				

TABLE 17. — Micrograms of molybdenum per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	0.2	0.8	0.3	0.1	0.5	0.1	0.1	0.1				
Bones, leg	<0.3	0.5	<0.3	<0.3	3.7	4.4	5.5	5.0	Brains	<0.1	10.1	1.6
Bones, skull	1.1	<0.3	8.7	3.9	5.8	3.3	1.4	6.6	Bursae	<0.1	...	9.6
Bones, sternum	8	3	4	6	8	1	3	6	Gizzard linings	32.8	<0.1	4.5
Fat	0.5	0.1	...	<0.1	...	5.7	2.5	0.6	Hearts	0.5	<0.1	0.1
Feathers	4	10	55	10	5	51	25	27	Kidneys	124	124	122
Feet	<0.3	3.0	<0.3	<0.3	7.7	0.8	2.6	3.6	Lungs	<0.1	<0.1	<0.1
Gizzard muscles	1.0	1.2	6.1	2.3	3.0	2.7	1.4	0.4	Reproductive organs	6	9	28
Intestines	<0.1	4.1	12.1	24.9	50.0	23.0	7.4	0.3	Pancreases	27	19	25
Livers	24	18	14	10	28	33	59	82	Spleens	43	1	6
Muscles, leg	1.4	0.1	6.6	0.2	0.1	<0.1	1.1	0.4	Thymuses	11	...	2
Muscles, sternal	1.0	0.3	<0.1	0.5	1.0	<0.1	<0.1	1.8				

TABLE 18. — Micrograms of nickel per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
od	0.01	0.04	75.18	0.06	0.01	0.04	0.01	0.01				
nes, leg	2	2	2	3	24	4	7	2	Brains	10	10	8
nes, skull	11	10	14	3	3	2	7	3	Bursae	55	..	40
nes, sternum	6	5	5	6	4	2	3	2	Gizzard linings	100	57	185
	9	67	...	183	...	271	225	134	Hearts	1	6	8
thers	68	56	81	86	84	78	83	53	Kidneys	1	20	8
t	7	2	10	3	5	2	3	10	Lungs	2	37	7
zard muscles	10	34	5	36	42	19	10	13	Reproductive organs	17	52	47
estines	19	123	144	135	251	255	141	110	Pancreases	10	95	28
ers	3	8	11	5	21	12	14	13	Spleens	11	17	19
scles, leg	36	3	80	28	28	8	451	51	Thymuses	20	..	106
scles, sternal	9	2	3	1	9	1	2	5				

TABLE 19. — Micrograms of silver per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
od	0.43	0.03	0.05	<0.15	<0.15	<0.15	<0.15	<0.15				
nes, leg	3	3	5	4	7	6	4	2	Brains	1	4	6
nes, skull	4	4	3	4	3	2	4	6	Bursae	13	..	2
nes, sternum	6	3	4	5	5	3	3	3	Gizzard linings	4	5	25
	<0.2	15.5	...	2.2	...	15.5	15.7	14.7	Hearts	<0.2	3.7	<0.2
thers	23	10	13	5	13	18	14	12	Kidneys	<0.2	<0.2	0.5
t	4	3	4	5	1	8	6	3	Lungs	0.2	0.7	0.3
zard muscles	2.5	1.4	6.7	3.1	2.6	9.2	0.5	7.7	Reproductive organs	7	7	7
estines	2	3	18	8	47	10	2	3	Pancreases	<0.2	1.8	1.1
ers	0.2	<0.2	0.4	0.7	0.4	0.9	<0.2	<0.2	Spleens	6	8	1
scles, leg	13.6	<0.2	16.8	<0.2	8.7	5.5	16.3	15.7	Thymuses	0.9	..	0.7
scles, sternal	6	6	8	9	10	13	10	12				

TABLE 20. — Micrograms of strontium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
od	4.8	0.9	0.2	3.3	0.8	1.8	0.4	2.0				
nes, leg	<15	<15	<15	<15	<15	<15	<15	<15	Brains	16	6	5
nes, skull	<15	<15	<15	<15	<15	<15	<15	<15	Bursae	44	...	17
nes, sternum	<15	<15	<15	<15	<15	<15	<15	<15	Gizzard linings	30	45	60
	49	42	...	198	...	148	84	250	Hearts	37	23	33
thers	92	94	96	43	82	91	115	89	Kidneys	59	59	110
t	<15	<15	<15	<15	<15	<15	<15	<15	Lungs	97	82	80
zard muscles	26	73	106	106	63	58	71	71	Reproductive organs	60	59	42
estines	30	45	273	38	200	30	55	104	Pancreases	13	24	40
ers	24	48	44	44	15	22	20	64	Spleens	126	211	85
scles, leg	40	41	28	51	78	88	61	42	Thymuses	18	...	41
scles, sternal	39	37	34	51	44	43	39	51				

TABLE 21. — Micrograms of tin per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	3	7	3	8	7	2	2	2				
Bones, leg	<8	<8	<8	<8	<8	<8	<8	<8	Brains	6	4	5
Bones, skull	<8	<8	<8	<8	<8	<8	<8	<8	Bursae	5	..	<2
Bones, sternum	<8	<8	<8	<8	<8	<8	<8	<8	Gizzard linings	<2	6	78
Fat	<2	<2	..	<2	..	<2	<2	<2	Hearts	4	5	5
Feathers	16	37	30	45	35	21	35	24	Kidneys	5	8	5
Feet	<8	<8	<8	<8	<8	<8	<8	<8	Lungs	47	89	42
Gizzard muscles	<2	<2	9	<2	<2	<2	<2	<2	Reproductive organs	28	23	6
Intestines	<2	<2	<2	<2	<2	10	<2	<2	Pancreases	4	4	4
Livers	14	13	26	31	19	15	9	11	Spleens	28	94	21
Muscles, leg	<2	<2	<2	<2	<2	<2	<2	<2	Thymuses	4	..	4
Muscles, sternal	<2	<2	<2	<2	<2	<2	<2	<2				

TABLE 22. — Micrograms of titanium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	2	2	3	2	5	1	5	31				
Bones, leg	13	30	12	<8	10	9	11	11	Brains	11	11	5
Bones, skull	22	22	16	21	13	13	16	15	Bursae	>700	...	341
Bones, sternum	22	10	15	8	20	<8	8	10	Gizzard linings	>700	>700	>700
Fat	74	>700	...	427	...	>700	>700	146	Hearts	34	22	39
Feathers	>700	>700	>700	>700	>700	>700	>700	>700	Kidneys	19	3	27
Feet	21	24	14	20	17	23	41	16	Lungs	301	316	109
Gizzard muscles	55	44	99	50	282	63	60	87	Reproductive organs	41	15	87
Intestines	81	24	3	56	52	24	74	44	Pancreases	7	5	43
Livers	65	66	143	52	38	14	14	21	Spleens	38	109	68
Muscles, leg	69	103	33	<1	101	55	3	67	Thymuses	24	...	39
Muscles, sternal	122	448	103	358	277	700	303	483				

TABLE 23. — Micrograms of vanadium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga				Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult		All Ages		
Blood	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01				
Bones, leg	92	78	44	102	76	108	89	19	Brains	<0.5	0.6	4.4
Bones, skull	47	48	140	113	120	50	137	94	Bursae	5	..	16
Bones, sternum	113	60	138	136	139	50	60	137	Gizzard linings	32.7	<0.5	22.7
Fat	5	4	...	6	...	1	1	1	Hearts	1.0	0.8	0.8
Feathers	>100	96	>100	>100	33	>100	>100	>100	Kidneys	1	2	4
Feet	121	128	42	140	118	37	130	122	Lungs	2.2	0.6	0.8
Gizzard muscles	1.4	<0.5	8.6	<0.5	0.9	<0.5	<0.5	13.0	Reproductive organs	2.1	1.4	0.5
Intestines	2.7	<0.5	14.2	3.4	25.0	2.0	2.7	4.6	Pancreases	0.9	0.9	<0.5
Livers	0.5	2.1	2.1	1.0	0.6	0.6	0.7	2.6	Spleens	2.8	3.1	<0.5
Muscles, leg	2	15	18	38	20	13	15	12	Thymuses	<0.5	..	1.2
Muscles, sternal	0.5	3.1	<0.5	2.1	1.3	4.0	1.2	1.2				

TABLE 24. — Micrograms of zinc per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga			Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult	All Ages		
od	40	39	39	35	34	34	35	35			
es, leg	462	400	450	450	437	525	525	800	Brains	675	950	800
es, skull	637	525	525	450	525	450	525	612	Bursae	562	...	344
es, sternum	500	475	400	487	500	525	537	912	Gizzard linings	925	637	349
	365	689	...	575	...	776	612	1,140	Hearts	2,750	2,800	2,687
thers	23,750	23,750	27,500	27,500	37,500	28,750	33,750	32,500	Kidneys	1,312	1,225	1,425
t	475	450	612	475	675	500	837	600	Lungs	825	1,075	862
zard muscles	3,125	3,625	3,250	3,000	3,000	2,875	2,750	3,250	Reproductive organs	552	769	689
estines	4,125	2,500	2,875	3,625	1,539	3,250	2,500	3,000	Pancreases	2,062	2,225	2,500
ers	1,675	2,187	2,350	2,150	1,837	2,350	2,500	1,025	Spleens	573	757	521
scles, leg	1,300	1,175	1,300	1,150	1,175	1,050	1,200	1,112	Thymuses	403	...	400
scles, sternal	425	500	1,200	437	450	437	600	500				

TABLE 25. — Micrograms of zirconium per gram of ash in body parts of hen pheasants collected from three areas in Illinois.

	Sibley			Humboldt		Neoga			Sibley	Humboldt	Neoga
	4 Mo.	7 Mo.	Adult	7 Mo.	Adult	4 Mo.	7 Mo.	Adult	All Ages		
od	1.04	0.05	0.63	0.30	0.49	<0.05	0.28	0.55			
es, leg	3	47	51	2	105	17	17	106	Brains	3	59	14
es, skull	188	119	163	23	126	82	90	450	Bursae	151	...	45
es, sternum	9	20	177	271	25	24	9	96	Gizzard linings	291	251	438
	74	374	...	227	...	385	14	355	Hearts	7	26	12
thers	145	343	439	247	258	300	375	350	Kidneys	<0.5	<0.5	1.9
t	3	17	131	75	46	118	12	1	Lungs	3	28	14
zard muscles	363	25	49	28	56	29	32	74	Reproductive organs	161	132	303
estines	49	29	91	214	104	11	42	46	Pancreases	4	58	52
ers	131	120	62	10	37	115	60	15	Spleens	10	68	25
scles, leg	29	27	3	2	8	1	24	47	Thymuses	98	...	6
scles, sternal	6	10	7	11	5	47	59	217				

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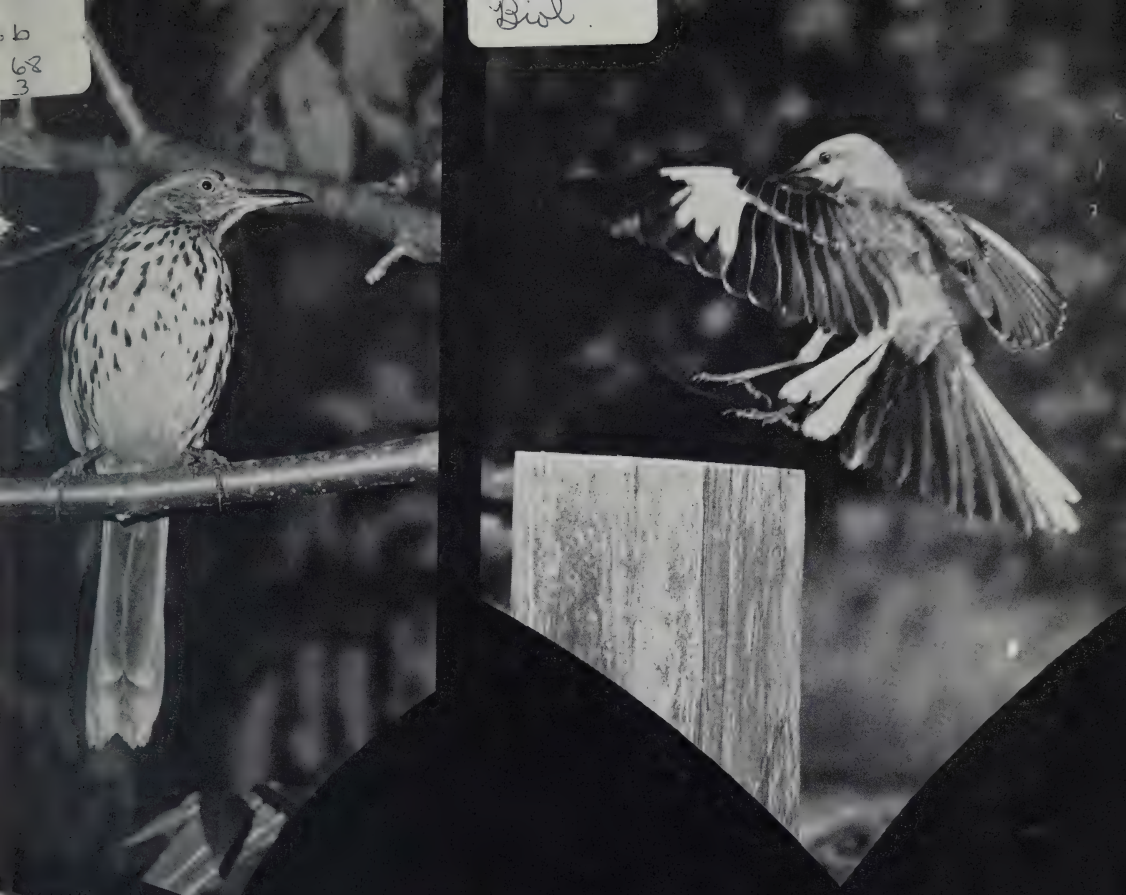

ILLINOIS BIRDS: Mimidae

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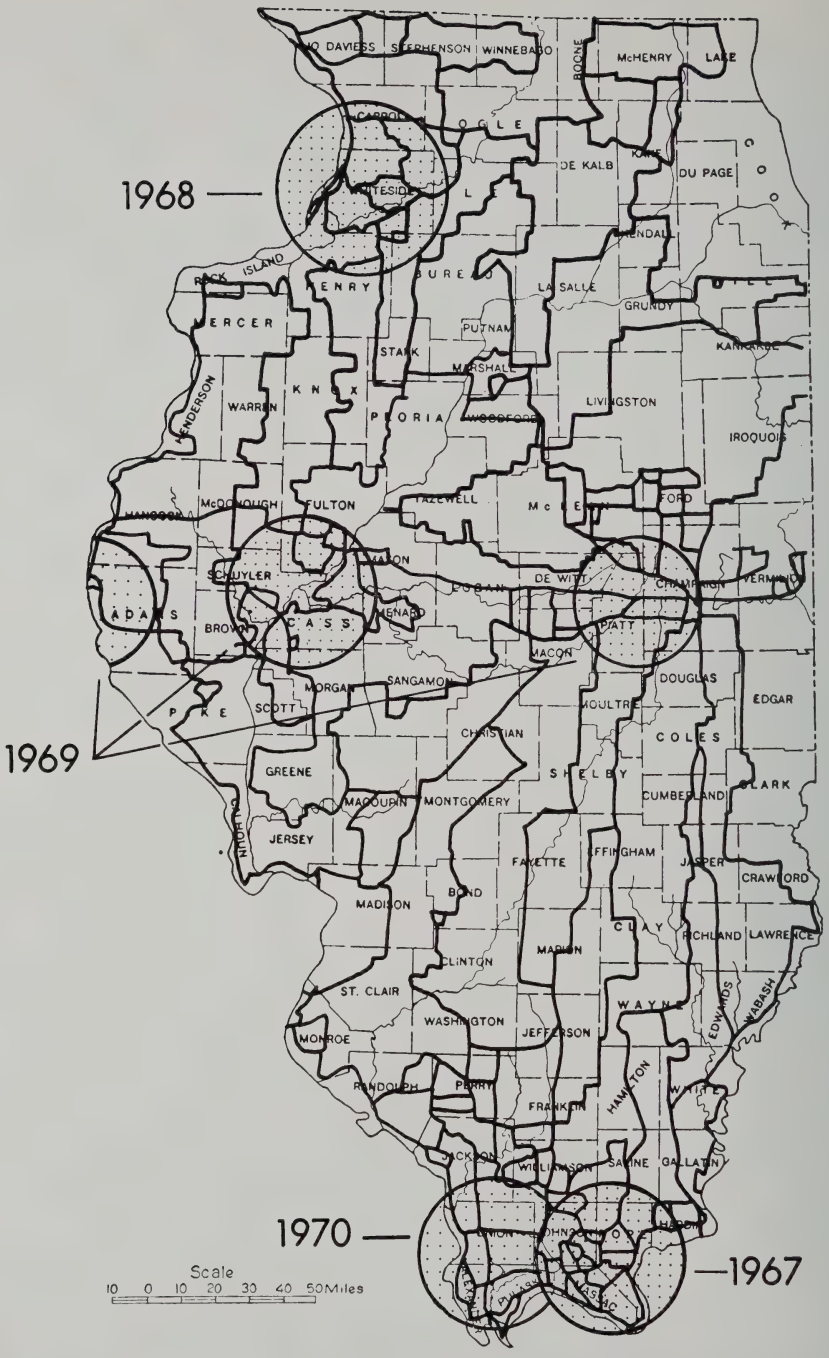

Fig. 1. — Routes travelled in summer, 1957–1969 to study breeding distribution of the birds of Illinois. The encircled areas were special study areas where daily censuses of migrants and nesting populations of birds were carried out, 1967–1970.

ILLINOIS BIRDS: Mimidae

Richard R. Graber, Jean W. Graber, and Ethelyn L. Kirk

IT MAY SEEM SURPRISING to many people that Illinois is still very poorly explored ornithologically, specially in any quantitative sense. In terms of real nderstanding of what bird populations are, or of what hey do, the study of Illinois birds is little advanced from vhat it was a century ago.

The accelerating changes in the land, which began ven before young Robert Ridgway started his studies of llinois birds in the 1860's, have brought us to a poten- ially precarious ecological state. As a species, man is rowding other living things out of existence without nowing whether or to what extent he is dependent upon iem. Now, increasingly, we need knowledge that there little time to acquire. We need more than just a list f the state's various natural resources. We need the nswers to a great many questions — questions on the istribution of populations, their reproductive potential nd food habits, their energy and habitat requirements, ieir migration routes, and ultimately their ecological elationship to every other part of the environment. The nswers will come, if at all, only through the efforts of large number of dedicated students, bird students of all ges, throughout the state.

The series of papers on Illinois birds, of which this is e first, hopefully will provide a foundation for the work those students. The papers will attempt to summarize hat has been recorded about Illinois birds. The series, hen complete, will include information on all of the ecies known to occur in Illinois, past and present. The apers are based primarily on (1) a compilation of data om published literature, (2) the authors' field notes and ose of Benjamin T. Gault, and (3) specimens in the ientific collections of the Natural History Survey and the nicago Museum of Natural History.

Unless otherwise stated, our discussions of the various ecies of birds refer only to the species in Illinois. To ep the work within some reasonable bounds, we have sentially ignored literature and data other than that for inois. Even a complete summary of the Illinois litera- re is not entirely practicable. On just the family Mimi- e, for example, we have about 1,500 references. To mmarize information from so many sources we adopted olicy of emphasizing those data which could be readily antified, and have put as much of the information as could into figures and graphs. The graphs on the an- al cycle are based on the literature for the extremes of gration and nesting dates, and on our own field work, ecially daily counts made mainly by R. R. Graber in special study areas (Fig. 1) during 1967, 1968, 1969, and 1970. In each area counts were made along a care- fully selected route varying in length from 80 to 105 miles in different regions. The routes were chosen to provide the maximum counts for the greatest number of species. Depending primarily on the numbers of birds seen, a route usually required 8–12 hours to cover. Each day, 4–6 hours were spent on woody habitats, 1–2 hours on open fields, 1 on aquatic habitats, and the rest on roadside habitats (driving). In making migration cen- suses, it was not our goal to obtain the maximum count possible for a particular species, but to get a representa- tive count for each species in relation to all the rest. We were interested in daily and seasonal variation in the numbers of all species.

Obviously our 1-year studies in different regions of the state cannot truly represent either the whole state or any sizable part of it. These studies were intended only as comparative reference points for other workers. It is our hope that, over the years, other students will make quantitative studies in every county in the state. Par- ticularly needed are data on the variations of populations from year to year in the same area, following the fine example of Dr. S. C. Kendeigh and his students in east- central Illinois.

The figures showing seasonal variation in egg laying are based on our repeated searches of the same areas throughout the breeding season.

We have prepared Illinois distribution maps for all of the native species, even those which we suspect nest in every township of Illinois. We adopted this policy especially to encourage students to fill in the gaps. It is a mistake to make assumptions about any phase of the biology of a population. Distribution patterns are not static, especially in this time of accelerating habitat de- struction, and as yet we do not truly know the distribution of any species in Illinois. Hopefully, students throughout the state will be encouraged to undertake county-wide or township studies to work out both the geographic and ecological distribution of each species in great detail. Only from the vantage point which such detailed studies provide can we see how populations and distributions change. The maps are based on our own field work, and on the literature when the published record included precise details on date and locality. Our references to regions of the state — north, central and south — follow Smith & Parmalee (1955).

In drawing up the North American distribution maps, we have tried to be conservative, drawing limits at points where the species was of fairly regular occurrence. There are altogether too few recent faunistic papers from which to work out the broad distribution of each species, and for some regions our judgments as to the patterns of distribu- tion were based on old literature. The maps are based

This paper, in the biological notes series, is published in part with ate funds. Dr. Richard R. Graber is a Wildlife Specialist in the ion of Wildlife Research of the Illinois Natural History Survey. Dr. Jean Graber is a Research Assistant Professor of Animal Science at the Uni- ty of Illinois. The late Miss Ethelyn Kirk served as Technical As- nt in the Section of Wildlife Research at the Survey.

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on the American Ornithologists' Union Check-list of North American Birds (1957), and more than a hundred regional faunistic works.

Nomenclature for birds follows the A.O.U. Check-list unless otherwise stated. For plant names we have followed three references, Jones (1963), Fernald (1950), and Rehder (1947). For insect nomenclature, we have followed primarily Borror & DeLong (1964).

Except for the classic studies of Forbes (1879, 1880, and 1883), there would be almost no information on the foods of most Illinois birds. Though old, the studies are valuable especially for comparative purposes. For the many students who do not have access to the Forbes papers, we have summarized some of his data, usually in graphic form.

We have discussed subspecific populations and other specimen-related data only for those species for which we have sizable series of recent specimens, i.e., specimens collected within the past 5–10 years. Thus, in the Mimidae, we have presented no specimen data for either the brown thrasher or mockingbird, because the number of recent Illinois specimens in existence is too small. In the case of the catbird, the television tower kills have provided us with an excellent series of specimens in fresh fall plumage, and we have discussed variation in this species. The state research collection at the Natural History Survey in Urbana continues to grow, and in time we hope to present specimen data for most of the Illinois species. In our studies in various parts of the state, we have come to realize how extremely variable are the problems which bird populations face from place to place. Not only do these problems vary from northern to southern Illinois, but they may differ greatly even in adjacent counties. This heterogeneity of populations and their problems may be the most important single fact we can tell other students about the birds of Illinois, and we will never understand how populations survive without massive detailed information on this variability.

In this report it was not feasible to cite all, or even most, of the papers that presented data (e.g. arrival or departure dates) for a given species. By that procedure the text would have been an almost endless list of references, with the manuscript prohibitively long. Generally, we have not included data from newspapers.

For quick references on the Illinois avifauna the useful distributional checklist by Smith & Parmalee (1955), birds of the Chicago region by Ford (1956), Chicagoland birds by Smith & Beecher (1958), and the checklist for southern Illinois by George (1968) are available in many libraries.

Unless otherwise stated, the photographs were made in Illinois by the authors, and represent wild birds.

Many people helped us in one way or another with this project, and most of them will be referred to under the species accounts. Here we wish to acknowledge some who helped in special ways, as in the use of scientific collections and other research facilities. We are very grateful to Paul W. Parmalee, Milton D. Thompson, and John Paul of the Illinois State Museum, Emmet R. Blak and Melvin A. Traylor of the Chicago Museum of Nat ural History, Philip S. Humphrey and Alexander Wet more of the U.S. National Museum, William George an John D. Parsons of Southern Illinois University, Donal F. Hoffmeister of the University of Illinois, and Joh Wanamaker of Principia College.

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O. F. Glissendorf provided valuable suggestio throughout the planning of the publications, and edit the final manuscript. Richard Sheets prepared the fin line drawings, and Wilmer Zehr, the final photograph prints.

To Edythe J. Kirk of the University of Illinois Libra we owe a special debt of gratitude for her kind encourag ment and support in publishing the work.

MOCKINGBIRD *(Mimus polyglottos)*
(Fig. 5)

Spring Migration

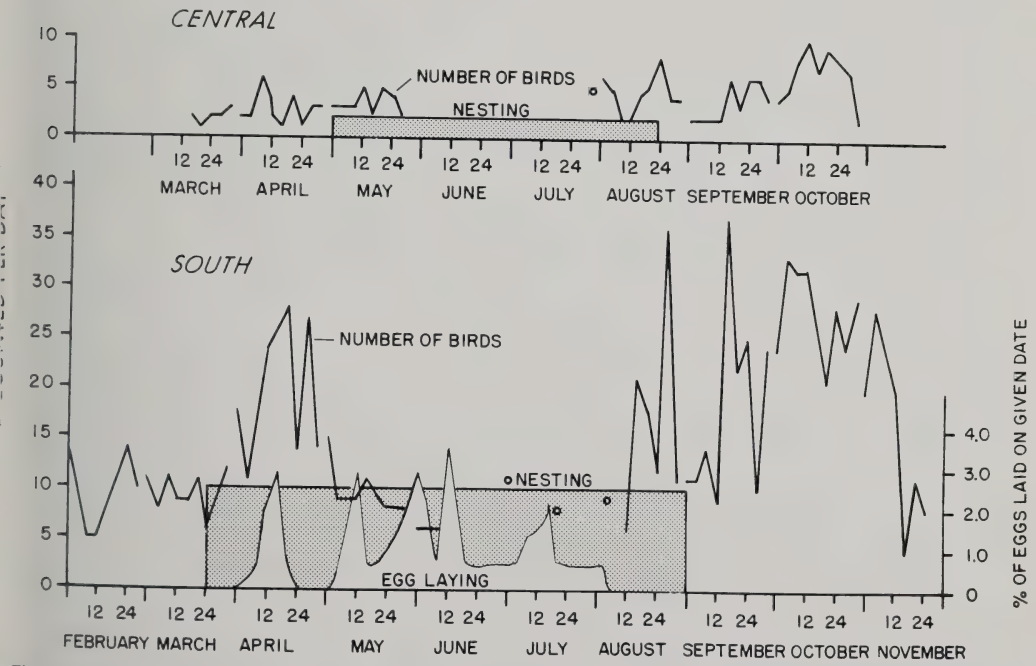
The Illinois literature is almost devoid of direct references to migrations of the mockingbird. The only clue available as to the nature of the migration was provided by a specimen killed with a group of night migrants at a television tower in Champaign County May 7, 1956 (Brewer & Ellis 1958). As indirect evidence of the mockingbird's migration there are the many records of mockers appearing in northern Illinois in late April (especially after April 17) and May (Clark & Nice 1950, Coursen 1947, Ford 1956, and others).

The spring migration is somewhat obscured by the presence of mockingbirds in winter in many parts of the state, but even in southern Illinois our censuses showed the mockingbird population fluctuating seasonally in a pattern that suggested migration (Fig. 2). Both in southern and central Illinois the highest spring counts were in April. The distribution of sightings of mockingbirds reported in the literature for northern Illinois and our census data for the central and south indicate a timetable for the mocker similar to that of the brown thrasher.

Distribution

The general distribution of the mockingbird is shown in Fig. 3. In recent years mockers have been reported in winter throughout much of the breeding range, and with increasing frequency, even north of the main breeding range (Andrews 1967). There are recent nesting records in the northern tier of Illinois counties but there are still no published nesting records for most of the counties, even in southern Illinois (Fig. 4). At least as early as 1933 a mockingbird nest was reported north of the Illinois line in Wisconsin (Van Sickle 1942), yet even today the mockingbird population is sparse north of the central zone. Ridgway (1889) and Ferry (1907) pointed out that the distribution of the mocker was irregular. Population densities of mockingbirds are still highly variable from place to place. For example, mocker populations are notably higher in southeastern Illinois than in the southwest.

Even before the turn of the century, it was recognized that the mockingbird was extending its Illinois range northward (Forbes 1880). A number of observers have provided important reference points on the progression of the range extension (Fig. 4). Silloway (1902) found mockingbirds nesting only "sparingly" in northern Ma-


CENTRAL
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FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER

Fig. 2. — Nesting and migration seasons of the mockingbird in different regions of the state (see Fig. 1). Spring and fall graph lines show the highest daily counts of each 3 days (left hand scale). The lines are interrupted where data have not been collected. Shaded block indicates length of the nesting season and level of adult nesting population. Egg-laying graph line (right hand scale) is based on repeated searches of roadside habitat throughout the nesting season.

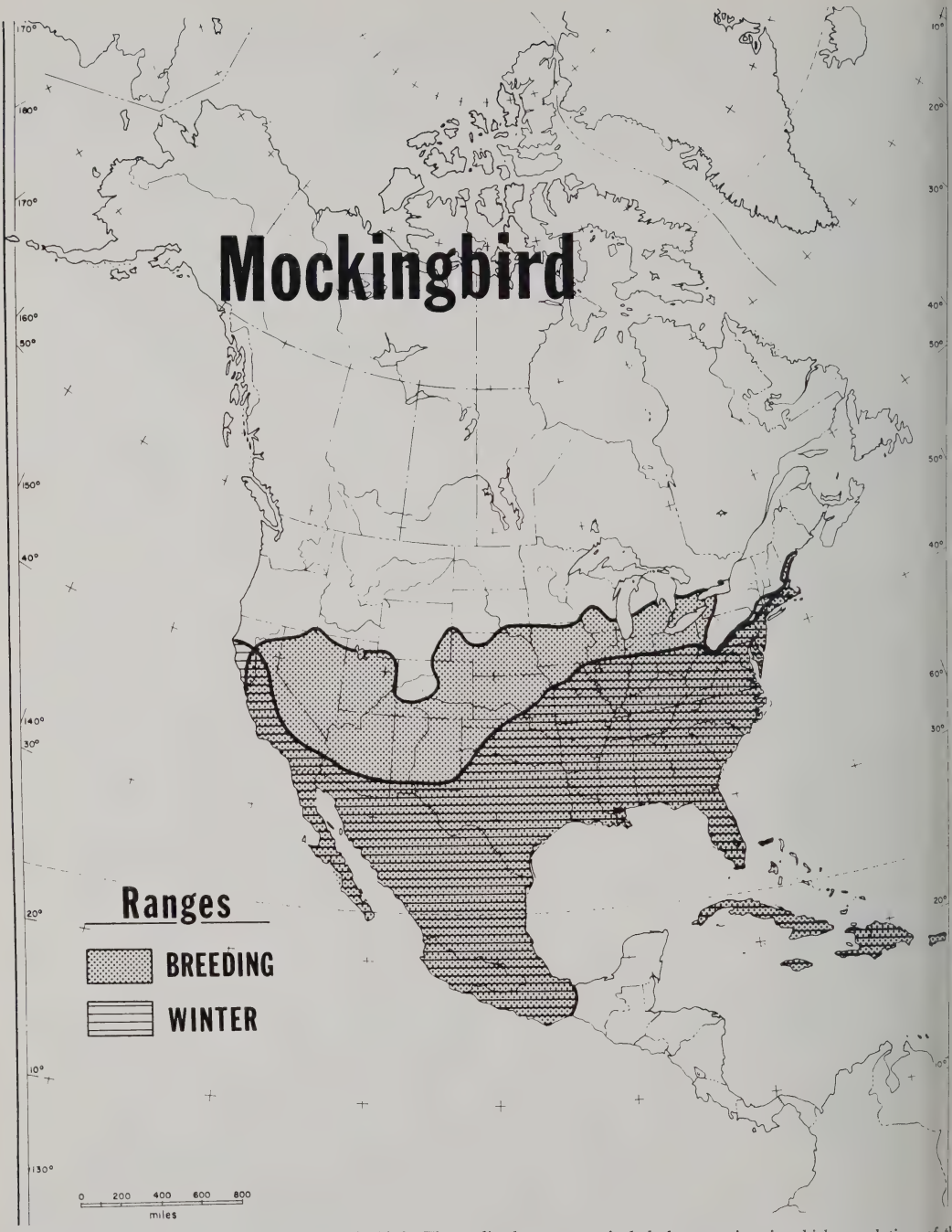


Fig. 3. — General distribution of the mockingbird. The outlined range may include large sections in which populations of th species are thin or even absent, because of the nature of the terrain and paucity of suitable habitat.

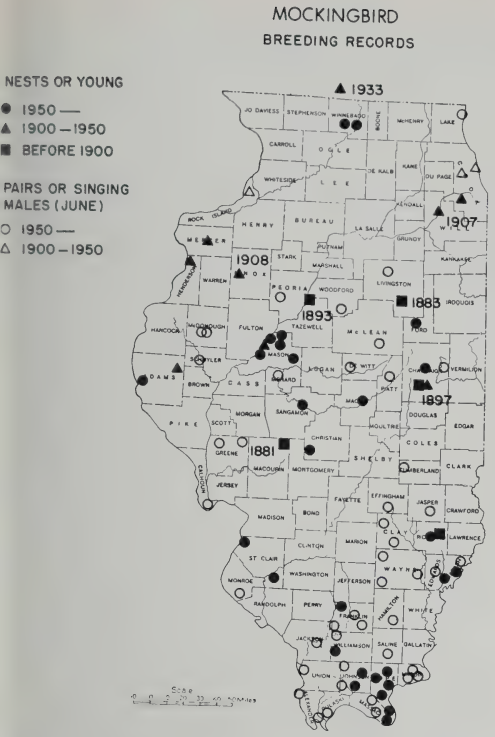


Fig. 4. — Breeding records for the mockingbird in Illinois. Singing male" records are for June only. The dates represent rly records of the species for the locality.

upin County in 1881. In Adams County, Musselman 938) noted that mockers were of irregular occurrence ior to 1933, but following a mild winter in 1936 the ecies was common in the 1937 nesting season. Bush 934–1935) also noted an increase in the southern part the state after 1933. In Champaign County, Smith 923) found mockingbirds well established as permanent sidents by 1923. Even earlier, Mundt (1883) found sts each year, and reported the mocker population in- easing in Livingston County (Fig. 4). Prior to 1893 urchison (1893) found the mockingbird common in rmilion County but noted that the species was then coming scarce.

esting Habitats and Populations

Like the thrasher, the mockingbird has much more lerance of open field habitats than does the catbird. stal (1913) found more mockingbirds than thrashers the sand prairie areas of Mason County, and Holland ersonal communication) also suggested that mocking- rds have an affinity for sand areas in western Illinois. t, a fairly wide tolerance of soils is indicated by the species' presence on the black soils of the eastern part of the state and the red soils of southern Illinois.

Except for the statewide strip censuses (Graber & Graber 1963), there are almost no published measurements of mockingbird nesting populations in Illinois, and other types of censuses are needed.

The mockingbird faces much the same kinds of habitat problems as the thrasher. Forest, even forest edge and modified forest habitat, such as in old residential areas, is of even less value to the mocker than to the thrasher. Edge habitats in open country are the most favored by both species, and these are the habitats in greatest peril. In general, woody edge plantings in farmlands are rapidly being destroyed, and the mockingbird does not have a habitat reservoir in central and northern Illinois that is not declining in acreage. A possible exception is new residential habitat, but its value to a mocker is unknown. We have noticed that farmsteads are a favorite nesting habitat for the mocker in the south, but abandoned farms much less so, as if the presence of humans was important to the bird in this situation.

Our list of plants used by mockers for nesting (Table 1) represents principally southern Illinois and is surely incomplete even for that region. Our records represent mainly roadside nestings, and a more random study would be of great interest. Our data probably also minimize the importance of multiflora rose *(Rosa multiflora)*, because we had difficulty finding nests in this plant. In central Illinois Hess (unpublished notes) found osage orange *(Maclura pomifera)* to be the favorite nest plant, and in more recent years, multiflora rose has been used. There are no data on nest plants in the north.

We have no information on territory size of the mockingbird. The closest we have found contemporaneous active nests along roadsides was 275 feet, a much wider spacing than shown by catbirds in similar habitat.

Table 1. — Plants used by mockingbirds as nest sites in southern Illinois.

Species	Percent of Total (77 Nests)
Red cedar *(Juniperus virginiana)*	48
Osage orange *(Maclura pomifera)*	9
Japanese honeysuckle *(Lonicera japonica)*	8
Sassafras *(Sassafras albidum)*	7
Multiflora rose *(Rosa multiflora)*	5
Grape *(Vitis* sp.*)*	3
Catalpa *(Catalpa* sp.*)*	3
Greenbrier *(Smilax* sp.*)*	3
Trumpet-creeper *(Campsis radicans)*	3
Mulberry *(Morus* sp.*)*	3
Snowberry *(Symphoricarpos* sp.*)*	1
Plum *(Prunus* sp.*)*	1
Hackberry *(Celtis* sp.*)*	1
Virginia creeper *(Parthenocissus quinquefolia)*	1
Ash *(Fraxinus* sp.*)*	1
Red maple *(Acer rubrum)*	1
Elm *(Ulmus* sp.*)*	1
Linden *(Tilia americana)*	1

Fig. 5 (two photos). — Above, mockingbird carrying food to a nest of young. Right, same bird, approaching nest site in a sm
red cedar tree.

Nesting Cycle

Ridgway (1918, 1923) reported that mockingbirds could be heard singing throughout the winter in Richland County, even when the temperature was near zero. In Pope County we have noticed relatively little singing in winter, but a definite increase in song just before mid-March, a more pronounced increase in mid-April, and in fall a resurgence of song in early October. Though the mocker's talents are well known, little has been recorded about the vocalizations in Illinois. At Aledo, Greer (1919) heard a mocker mime 22 species of birds in an hour. The alarm note that we heard most often around nests was a sharp, staccato, crackling sound, similar in character to notes uttered in agitation by both catbirds and thrashers. Freeman (1950) has described the mockingbird's curious habit of periodically jumping 3 feet or so in the air from a perch, then landing at the same spot again. We have also seen mockers "wing-flashing," but have no data on the seasonal periodicity or function of either of these performances.

The nesting season of the mockingbird in southern Illinois lasts at least from March 24 (our earliest record of nest-building) to September 1 (our latest record of young fledged). Further study will probably show the season to be longer at both extremes, but most of the nesting surely falls in this period (Fig. 2). On our study area in 1967 most of the egg production occurred between April 8 and June 20 (Fig. 2), a much longer season than that of the thrasher in the same area. The egg-laying curve for the mockingbird has several peaks, and the species may be double brooded, but there was a high incidence of nest failures (see below), and banding studies are essential to learn the number of broods reared. The few nesting records available for central Illinois indicate the duration of the nesting season there to be from at least May 1 to August 23.

Data from a number of nests in southern Illinois show that one nesting cycle may take 33–36 days. Nest-building at one early nest required 7 days; laying, to the onset of incubation, took 3 days; and incubation time was 1

Fig. 6. — Mockingbird nest (not in situ) with eggs, about life size. The eggs, usually 3 or 4, are often pale green or greenish blue, blotched with reddish brown. These two eggs were chosen to show pigment varation.

days. The development of young to fledging took another 13 days. Nest-building may generally take less time later in the season; we found several early nests that looked complete but remained empty 3–4 days before laying began.

In southern Illinois, plant species used for nesting were about the same as those used by thrashers (Table 1). The height of mockingbird nests varied with the season, the average being just under 5 feet in April and May (28 nests), and nearly 7 feet in June, July, and August (32 nests). We have no explanation for the change. No instances of ground nesting have been reported for this species.

Clutch size in 52 nests in southern Illinois averaged 4.8 eggs, with clutch distribution as follows: 6 eggs, 2 percent; 5 eggs, 6 percent; 4 eggs, 59 percent; and 3 eggs, 33 percent. There was little decline in clutch size from April to July, in marked contrast to the nests of both catbirds and thrashers. The majority of mockingbird nests in central Illinois also had 4-egg clutches. (For more information on eggs, see Fig. 6.)

Cowbird *(Molothrus ater)* parasitism of mockingbirds has not been recorded in Illinois.

Mockingbirds had the poorest nesting success of the three mimids. In April-May only 9 percent of the eggs laid survived to produce fledglings (Table 2). On the basis of largely circumstantial evidence, we suspect that much of this mortality came from black rat snakes *(Elaphe obsoleta)*. We saw this predator near nests often, but rarely saw the actual predation. Mockers often attacked the snakes, pecking them vigorously, but with little apparent effect. The mockingbird's nesting efforts were more successful later in the season (Table 2), and most of the production of young came in July and August. More years of study and larger samples of data are needed to see if this is a consistent pattern. Thrashers nesting in the same area as mockingbirds had better nesting success early in the season. Mockingbird nests were generally more conspicuous than those of the thrasher, and the mocker population may have served as a cushion for nesting thrashers by absorbing the brunt of the predation. The rate of infertility, i.e., no embryonic development, was only 2 percent in the mockingbird population we studied, but one form of mortality more apparent in the mocker than the other mimids was the death of half-grown nestlings from unknown causes, but possibly cold and exposure. Such deaths accounted for 6 percent of all eggs in April-May nests, but only 1 percent in later nests. Because there is so much similarity in habitat between nesting thrashers and mockingbirds, the question of possible competition deserves study. We witnessed one fierce fight between birds of these two species near a mockingbird nest in Pope County.

There are virtually no data on nesting success of mockers north of southern Illinois.

TABLE 2. — Nesting success of mockingbirds in southern Illinois.[a]

April-May				June-August			
Number		Percent Fledged		Number		Percent Fledged	
Nests	Eggs	Nests	Eggs	Nests	Eggs	Nests	Eggs
28	100	9	9	33	108	28	26

[a] Nesting success computed by exposure-day method (Mayfield 1961).

Fall Migration

Summer and winter distribution records for the mockingbird show that a definite population shift occurs between the two seasons (Fig. 2), but the precise timing and nature of that migration are unknown. The appearance of mockers in northern Illinois from September to November (Clark & Nice 1950, Ford et al. 1934, and others) may represent fall migration, but from where? There are many records of mockingbirds "out of place" in the north in November (Lewis 1925, Perkins 1927, and others). These records suggest that there may be much random wandering by mockers in the fall, and that the migration patterns are not yet fully developed.

Our censuses of mockingbirds in central and southern Illinois showed that fall populations were two times higher than spring populations and three to five times higher than summer populations, day to day. The level in October was particularly high (Fig. 2). Do the high populations from August to November represent productivity, migration, or both? So far as we know, no mockingbird has been found among the thousands of night migrants killed in fall at television towers in Illinois, but the towers in southern Illinois where we would most expect kills are rarely checked. To resolve the problems of the mockingbird's migration, its timing and manner, intensive banding studies are needed.

Winter Populations

The distribution of winter records of mockingbirds in Illinois is shown in Fig. 7. The most extensive winter population data for the mockingbird and other species come from the annual Audubon Christmas counts. The counts indicate great variation in the population from year to year (Fig. 8), but the long-term trend has been upward in more recent years in all three regions of the state. In northern Illinois the frequency of occurrence of mockers on Christmas counts averaged less than 1 percent between 1900 and 1948, but 5 percent in the next 20 years. The censuses for southern and central Illinois show a marked increase in the number of mockingbirds, beginning especially in the 1950's (Fig. 8). To some extent this increase may represent increased participation in the censuses, but many observers in many different areas reported the same kind of change in the Midwest and North (see especially Andrews 1967), and we believe the increase is real. The statewide censuses show the same trend (Graber & Graber 1963). The Christmas counts also emphasize the variation in mockingbird populations from place to place. In southern Illinois, Richland

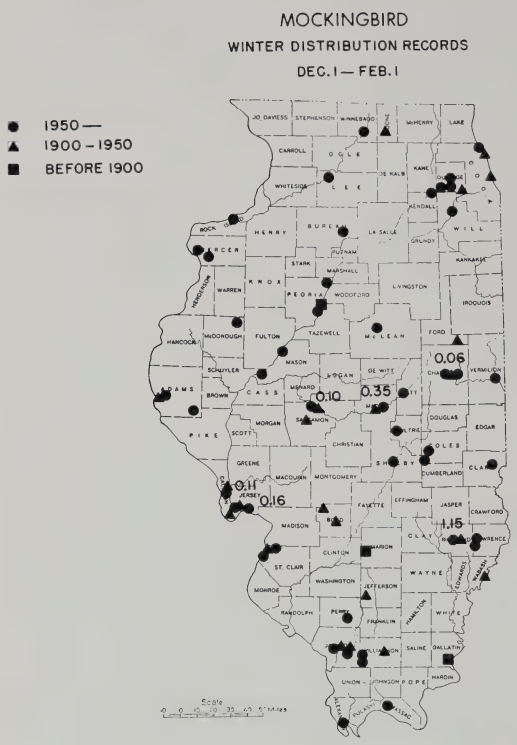


Fig. 7. — Winter records for the mockingbird in Illinois. The figures represent the long-term average of the number of mockers seen per party hour on the Audubon Christmas counts at localities with a long history of counts.

County, which had a notably high population in Rid way's (1889) time, has a consistently high winter cou to this day, and in central Illinois the counts in the D catur area are consistently higher than the Springfield ar Urbana counts (Fig. 7). The Christmas count data gi us a relative impression of the populations. The on measurements of the winter population in more absolu terms are those of Shaw and Stine (1955), Shaw (1961 and Axelson, et al. (1965), and the statewide str censuses.

The habitats used by mockingbirds seem much t same in summer and winter with high densities in ed shrub habitat both seasons. There is little utilization forest edge in winter, and virtually none in summer, b pastures and fallow fields are important to the bird both seasons. The importance of residential habitat the mockingbird in winter is unknown. Many write have commented on the relationship of mockingbirds multiflora rose in winter (Fig. 9), and the presence these rose hedges may have a definite bearing on the r cent extension of the winter range in the North (Eme & Woodruff 1968). Rose hips are thought to be an i portant winter food.

The only observation relating to homing phenomen in the mocker is that of Dyke (1956) who recorded mockingbird (recognizable because of its crippled foo at Princeton for at least four consecutive winters. Th also constitutes the only longevity record for the speci in Illinois.

Mockingbirds have been attracted to feeders in parts of the state. They are especially attracted to su and peanut butter, but also to asparagus berries, appl and the fruits of bittersweet (Schantz 1922, Campb 1953, and Smith 1923). In southern Illinois Ridgw (1918) noted that mockers were fond of raisins.

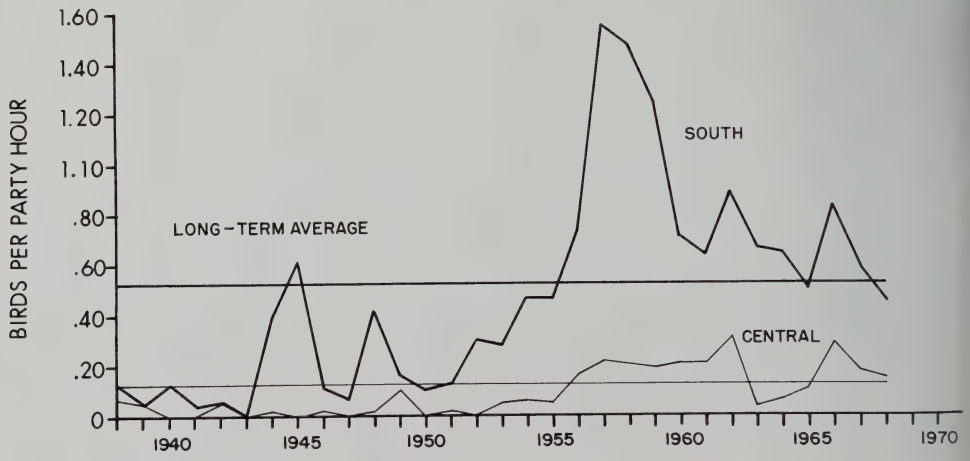


Fig. 8. — Annual variation in the number of mockingbirds seen per party hour on the Audubon Christmas counts in southe and central Illinois. The straight horizontal line represents the long-term average for the region.

Fig. 9. — Mockingbird in winter plumage, resting in a multiflora rose hedge.

ood Habits

Forbes (1880) examined only two specimens of mockgbirds in his food habits studies and little has been done the subject since. His specimens were taken near oomington, at least one of them in August. Sixty perit of the stomach contents consisted of Orthoptera. ther observers have recorded orthopterans, notably asshoppers, in the mocker's diet (Vestal 1913, and andercook 1923). Much of the foraging is done on the ound, and Vandercook (1923) observed a mocker takg insects under garden mulch in February. Besides rose os and the foods taken at feeders in winter (see above), ockingbirds take other kinds of fruit. In southern Illinois Steagall (1922) and Vandercook (1923) noted that persimmons *(Diospyros virginiana)* and hackberries (*Celtis* sp.) were important to the mocker. Also in southern Illinois, Ridgway (1929) found mockers feeding on the fruit of holly *(Ilex decidua),* and hawthorn *(Crataegus viridis)*. In central Illinois Musselman (1939) saw mockingbirds feed on bittersweet *(Celastrus scandens)* berries during the cold weather, until waxwings decimated the supply. A mocker weathered the winter near Wilmette eating frozen apples still on a tree (Schaub 1942), and at Glen Ellyn a bird fed on the fruit of yew (*Taxus* sp., Stofer 1944). There are no real quantitative data on the food habits at any season, and none on the food of the young.

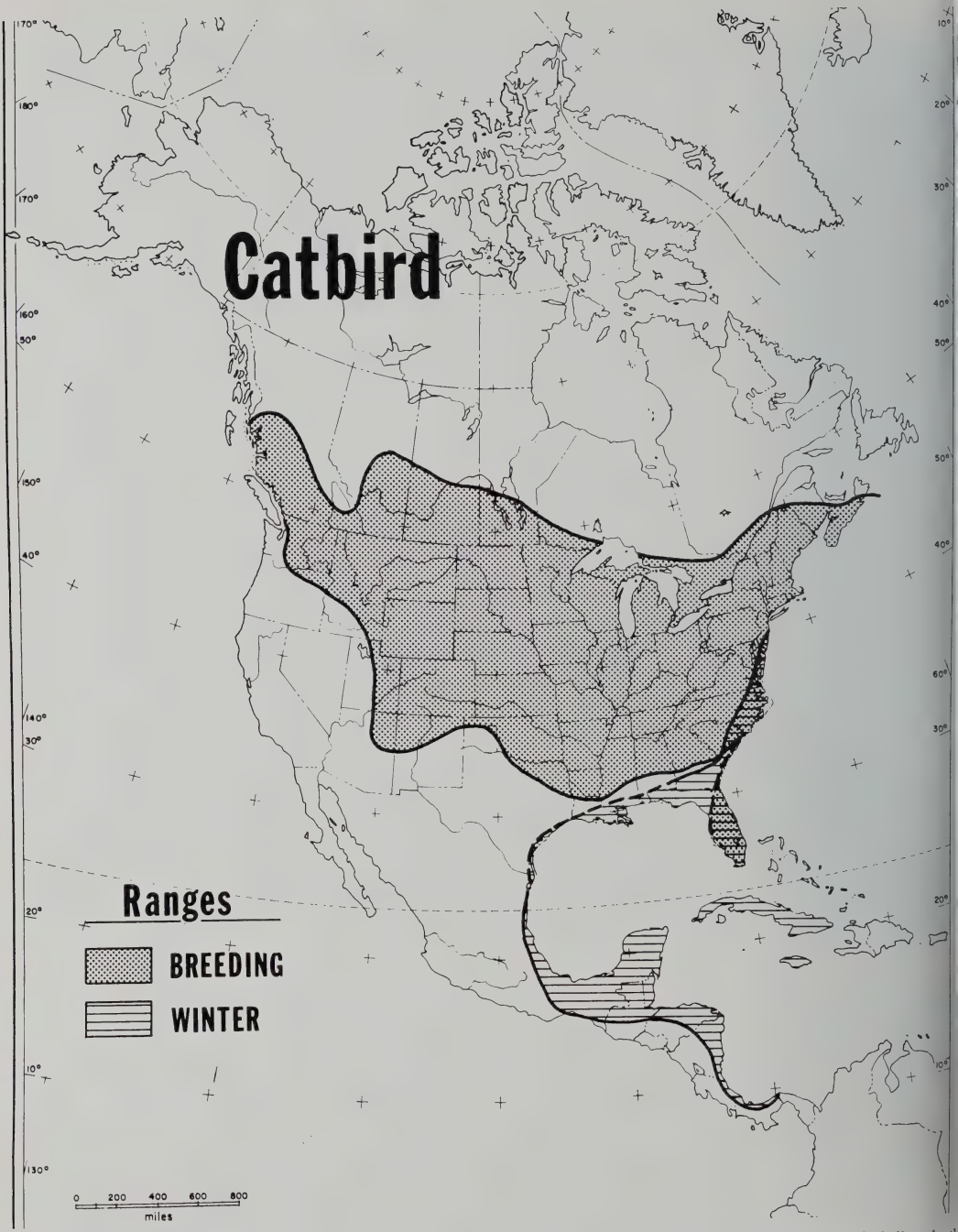
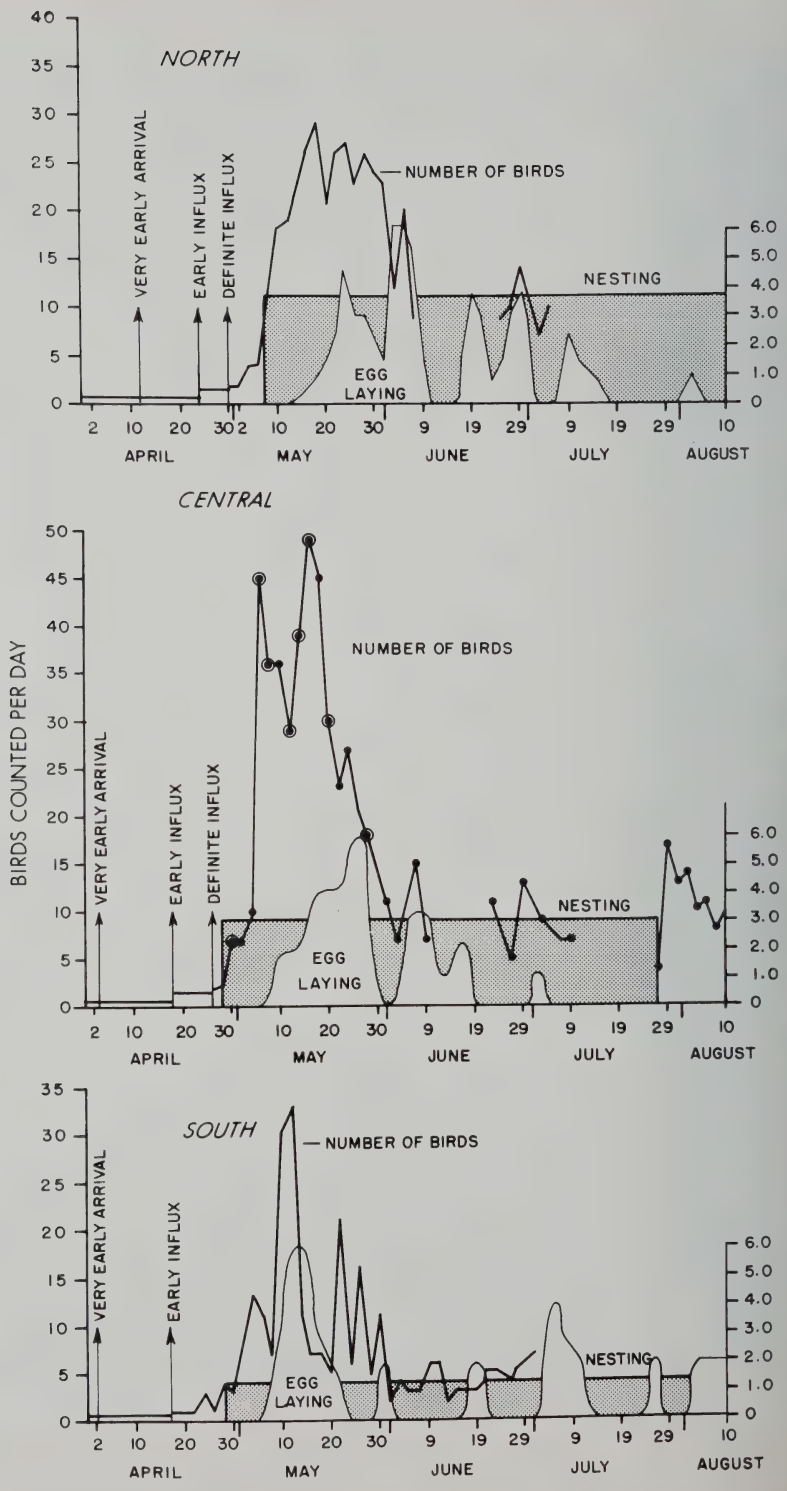


Fig. 10. — General distribution of the catbird. There are few breeding or winter records south and east of the dash lines in th U.S. The outlined range may include large areas in which populations of the species are thin or even absent because of the natu of the terrain and paucity of suitable habitat.

Fig. 11. — Catbird in fresh fall plumage. The pokeberries were tied to the branch as bait for the bird.


NORTH
VERY EARLY ARRIVAL
EARLY INFLUX
DEFINITE INFLUX
NUMBER OF BIRDS
NESTING
EGG LAYING
CENTRAL
BIRDS COUNTED PER DAY
NUMBER OF BIRDS
VERY EARLY ARRIVAL
EARLY INFLUX
DEFINITE INFLUX
NESTING
EGG LAYING
SOUTH
NUMBER OF BIRDS
VERY EARLY ARRIVAL
EARLY INFLUX
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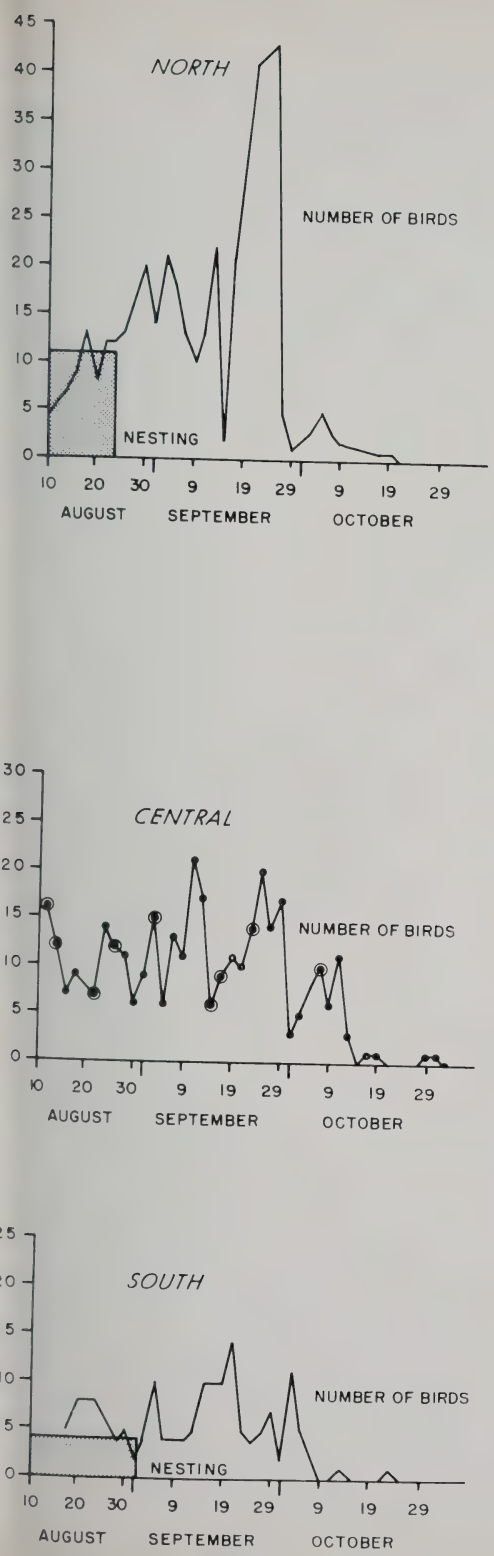
APRIL
MAY
JUNE
JULY
AUGUST



CATBIRD *(Dumetella carolinensis)*

(Fig. 10 and 11)

Spring Migration

So far as we know, catbird migration in Illinois is strictly nocturnal, spring and fall, but the only direct indication of the night flight in spring is a catbird killed with other night migrants at a television tower in Champaign County on the night of May 28-29, 1963.

Though there are a few winter records of catbirds in Illinois, the onset of the spring migration is conspicuous, and, in marked contrast to the early migration of the thrasher, shows little disparity in timing between the southern and the northern regions of the state (Fig. 12).

There are a few March (26–29) records of catbirds in Illinois (Blocher 1921, Schwager 1961, and others), and a few for early April (Beecher 1937, Cooke 1888, and others), but the early arrival dates recorded by most observers fall between April 17 and May 1, with usually no more than a week between early arrivals in the south (April 17) and the north (April 24). Definite influxes are often noted, April 26–28, and May 1, and, quantitatively, May is the month of catbird migration throughout the state (Fig. 12).

As in the case of the thrasher, the catbird's spring migration is particularly conspicuous in west-central Illinois, and least notable in the south (Fig. 12), perhaps reflecting the large amount of concealing cover in the south.

Nothing has been recorded on specific habitat requirements or preferences if any, of migrating catbirds, nor are there published data on the destinations of transient catbirds which pass through Illinois in spring.

Distribution

The general distribution of the catbird is shown in Fig. 10. The species probably nests in every township in Illinois, but published records are lacking for many counties (Fig. 13).

Nesting Habitats and Populations

Like the thrasher and mockingbird, the catbird is an edge species, but unlike them it is not nearly so tolerant of open spaces. Where the thrasher follows linear hedge plantings far out into the open cultivated fields, the catbird stays closer to more wooded areas. Still, on the basis of population density, edge shrubbery is the favorite habitat in most of northern and central Illinois (Table 3). Compared with thrashers, catbirds are much more toler-

Fig. 12. — Nesting and migration seasons of the catbird in different regions of the state (see Fig. 1). Spring and fall graph lines show the highest daily counts of each 2 days (left hand scale). The lines are interrupted where data have not been collected. Encircled points represent censuses in the Illinois valley; other points represent east-central Illinois. Shaded block indicates length of the nesting season and level of adult nesting population. Egg-laying graph line (right hand scale) is based on repeated searches of roadside habitat throughout the nesting season.

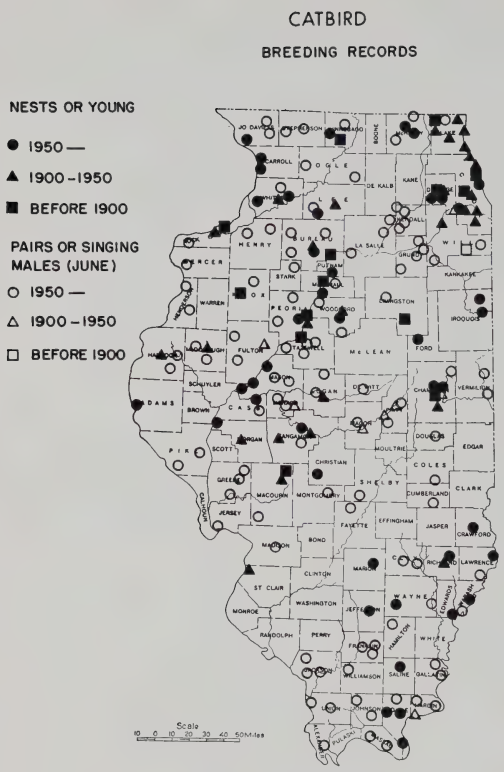


Fig. 13. — Breeding records for the catbird in Illinois.

ant of man, and there is an interesting variation from north to south in the use of urban residential habitat by catbirds (Table 3). In the north this habitat is relatively little used and in the south it is the most important habitat. The catbird, thus, has at least one expanding habitat.

The catbird is also a forest-edge species (Kendeigh 1944). In Piatt County, Weise (1951) found no catbirds nesting in floodplain or upland forest, but two to three pairs per 100 acres in forest edge. In Mason County, Gates (1911) considered the catbird a dominant species of hydrophytic thickets, and of secondary importance in hedges, orchards, and bottomland woods. Nehrling (1880) also felt that the catbird favored wet areas, and Beecher (1937), Robertson (1944), and others have recorded the species nesting in notably wet habitats. In southern Illinois especially we have found catbird nesting population to be highest in swampy situations.

We have summarized the available data on plant species used for nesting by catbirds (Table 4). They use thorny plants for nest sites, but not to the extent that thrashers do. In northern and central Illinois, grape (*Vitis* sp.) is much used by catbirds, not only for nest placement, but in nest construction. Barnes (unpublished notes) noted that a very high percentage of catbird nests contained sizable amounts of grape bark.

The only information on the size of a catbird's territory in the state is from southern Illinois, where Brewer (1955) recorded the area of activity of two nesting pairs to range from 0.16 to 0.36 acre. This is much smaller than the territories of brown thrashers in central Illinois (1.6+ acres, Hensley 1948). Our data also indicate small territories for catbirds; we have found active nests (with eggs) only 48 feet apart in a southern Illinois thicket.

Nesting Cycle

Ridgway (1925), Schantz (1931), and others believed that catbirds returned to the same nesting territory year after year. Banding records presented by Bartel (1935), Lincoln (1927), and Jurica, et al. (1959) tend to support this view, as catbirds banded in May and June were recovered in successive years at the places of banding. Bartel (1942) also banded a young catbird and recovered it the next year in the same area.

Like the thrasher, the catbird arrives singing in spring. Of the song, Ridgway (1889:108) reported that the song is conspicuous, sometimes brilliant, but in his performance there is too much deliberation, and the general effect is that he is merely practicing. The catbird's whisper song is especially soft (Schafer 1916). Catbirds mimic some sounds (Ridgway 1889:108), and also, like the mocker, sing at night (Farwell 1919, Musselman 1932). Singing drops off sharply after June, and during July and August songs are often subdued and incomplete with few birds singing. The cat call that gives the bird its name is heard increasingly later in the nesting season, along with an alarm note which we translate as a "chwurk."

The nesting season, from the beginning of nest-building to the fledging of the last young lasts from about April 28 to September 2 in southern Illinois, and from May 7 to August 24 in the north (Fig. 12).

One nesting cycle, from nest-building through fledging of young, took 29 days at Wilmette, Illinois (Davis 1942) but most nestings probably take slightly longer. We have known nests to remain empty 5 and 6 days before receiving the first egg, and have recorded incubation periods of 12–13 days for several clutches. Young usually fledged in 11–12 days. Davis (1942) felt that incubation was carried out exclusively by the female, setting about 20 minutes and taking off 5. He also reported that both sexes fed the young.

Data on the plants used for nest sites are summarized in Table 4. Most catbird nests are found at heights between 4 and 8 feet. Our sample of 85 nests from northern Illinois averaged 5.5 feet in height. Nests further south were higher, on the average — 6 feet in central Illinois (26 nests), and nearly 8 feet in the south (21 nests). We have no explanation for this trend. By comparison with the thrasher, catbirds place their nests high. A catbird nest located about 50 feet high in an elm in Peoria County (Loucks, unpublished note) was probably exceptional. We have found no record of a ground nest for this species.

Table 3. — Breeding populations of catbirds in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Edge shrubbery	15	150	1957–1958	Strip	North	Graber & Graber 1963
	21	52			Central	
	22	5			South	
Thickets	7	226	1937	Nest	Lake (N)	Beecher 1942
	13	46	1950	Nest	Jackson (S)	Brewer & Hardy 1950
Early shrub	..	72	1966	Nest	Vermilion (C)	Karr 1968
Late shrub	..	32	1966			
Block shrub areas	32	31	1957–1958	Strip	North	Graber & Graber 1963
	49	14			Central	
	107	1			South	
Orchard	36	5	1957–1958	Strip	North	Graber & Graber 1963
	78	3			South	
Second growth or cut-over woods	15	86	1937	Nest	Rock Island (N)	Fawks 1937
	15	106	1938			Fawks 1938
	56	7–25	1941–1944	Nest	Sangamon (C)	Robertson 1941, 1942, 1944
	46	22	1948			Robertson & Snyder 1948
Virgin floodplain forest	77	3	1948	Nest	Sangamon (C)	Snyder, et al. 1948
Grazed bottomland	93	6	1955	Nest	Macon (C)	Chaniot & Kirby 1955
Forest (all types including edge)	177	2	1957–1958	Strip	North	Graber & Graber 1963
	214	7			Central	
	340	+[b]			South	
Forest edge	55	0–7	1927–1948	Nest	Champaign (C)	Kendeigh 1944, 1948
	55	(0–12 per mile)	1949–1968	Nest	Champaign (C)	Kendeigh & Fawver 1949, Kendeigh & Forsyth 1959, Kendeigh & Barnett 1968
Modified woodland	28	43	1937	Nest	Lake (N)	Beecher 1942
Parkland estates	100	16	1915	Nest	Cook (N)	Eifrig 1915
Residential areas	160	1	1958	Strip	North	Graber & Graber 1963
	75	4			Central	
	98	22			South	
	8	75	1915	Nest	Richland (S)	Cooke 1916
Swampy prairie	67	3–6	1941–1944	Nest	Sangamon (C)	Robertson 1941, 1942, 1944

[a] We have converted all figures to read birds per 100 acres or birds per mile of edge (number of territorial males or nests × 2).
[b] Less than one.

For our sample of nests in northern and central Illinois, clutches averaged 3.7 eggs in May and June, and 1 in July and August (Table 5). Cowbird parasitism catbirds is apparently rare. The one Illinois record we now of was in a nest observed by Goelitz (1915).

Nehrling (1880) and Schantz (1931) believed that tbirds regularly produced two broods a year, but there e no observations on banded birds either to substantiate refute their view. The laying curve for catbirds in Illinois (Fig. 12) has several peaks, much like that of the ockingbird, but very different from the high-peaked aph for the thrasher. Most of the egg production comes May and June (Fig. 12). (For an illustration of the st and eggs, see Fig. 14.)

Nesting success of the catbird (Table 6) was quite nsistently higher than that of the thrasher. In northstern Illinois in late summer about two-thirds of the gs laid produced fledglings (Table 6). The only other ccess data available for catbirds in Illinois are those Finley (1917) who found that catbirds had the highest ccess (about 65 percent of eggs produced fledglings) of the common species on the Normal School campus at Macomb.

We can offer no reason for the catbird's high nesting success, compared with that of the other mimids, and there are few observations on the causes of nest failure in this species. Only about 2 percent of eggs in northern Illinois failed to develop embryos. Thompson (1958) and Baroody (1938) reported attacks by blue jays *(Cyanocitta cristata)* on catbird nests in northern and southern Illinois, and Ridgway (1921) observed a gray squirrel *(Sciurus carolinensis)* destroying a catbird brood in the south.

Fall Migration

In August and early September many if not most catbirds are in molt and their appearance is ragged. We have seen a few still molting heavily as late as September 22 in central Illinois, but many catbirds appear to have completed molting by September 10 and we have seen catbirds in fresh plumage as early as August 17.

When the fall migration of catbirds actually begins is unknown. Recorded departure dates from Illinois range

TABLE 4. — Plants used by catbirds as nest sites.

Species	Percent of Total Nests		
	North (121 Nests)	Central (31 Nests)	South (27 Nests)
Grape *(Vitis* sp.)	21	23	..
Dogwood *(Cornus racemosa), C. rugosa* and *C.* sp.	17	3	4*(flcrida)*
Sassafras *(Sassafras albidum)*	..	..	26
Hawthorn *(Crataegus* sp.)	7	6	11
Virginia creeper *(Parthenocissus quinquefolia)*	3	..	18
Elm *(Ulmus* sp.)	3	10	4*(alata)*
Gooseberry *(Ribes* sp.)	12	6	..
Crabapple and apple *(Malus* sp.)	1	10	4
Multiflora rose *(Rosa multiflora)* + *Rosa* sp.	6	3	4
Osage orange *(Maclura pomifera)*	1	13	..
Willow *(Salix* sp.)	2	10	..
Red cedar *(Juniperus virginiana)*	2	..	7
Black locust *(Robinia pseudoacacia)*	1	3	4
Plum *(Prunus* sp.)	..	..	7
Box-elder *(Acer negundo)*	2	3	..
Oak *(Quercus* sp.)	1	..	4
Sumac *(Rhus* sp.)	1	..	4
Bramble *(Rubus* sp.)	5	..	..
Ash *(Fraxinus* sp.)	1	3	.
Honeysuckle *(Lonicera* sp.)	4	..	..
Mulberry *(Morus* sp.)	4	..	..
River birch *(Betula nigra)*	..	3	..
Lilac *(Syringa* sp.)	..	3	..
Golden-bell *(Forsythia* sp.)	..	3	..
Elderberry *(Sambucus canadensis)*	2	..	..
Norway spruce *(Picea abies)*	1	..	..
Hazel *(Corylus americana)*	1	..	..
Spirea *(Spiraea* sp.)	1	..	..
Yew *(Taxus* sp.)	1	..	..

from mid-September to mid-October, with most falling in late September and early October. The catbird migration is almost over by October 10, but there are a few records for November and even fewer on into the winter (Fig. 12).

Our censuses indicate a definite increase in catbirds in August over the summer population (Fig. 12), and we judge that the southward movement begins by at least mid-August in northern and central Illinois. Our data show many more migrating catbirds in northern Illinois than in the south, with central Illinois intermediate in volume.

Only in northern Illinois did the total fall count exceed the spring count of catbirds. The low fall counts are enigmatic, for we would expect a population increase during the summer, and, hence, a high fall count. There are several possible explanations of the paradox. Among other things, the census method may be faulty, or the behavior of the birds so different in fall that they go undetected. The gradation in the fall population from high in the north to low in the south suggests the possibility that many of the northern catbirds are migrating eastward as well as southward (see below under Specimen Data).

TABLE 5. — Clutch sizes of catbirds in northern and central Illinois.

Months, Years	Total Number of Nests	Average Clutch	Percent of Nests with Clutches of:			
			5 Eggs	4 Eggs	3 Eggs	2 Eggs
May-June, 1967–1968	38	3.7	5	58	37	..
July-Aug., 1967–1968	9	3.1	..	22	67	11

The only fall recovery of an Illinois-banded catbird that we know of was reported by Laskey (1961). The bird, banded at Lisle, Illinois, May 19, 1960, by Dr. Edmund Jurica, was killed September 28, 1960, at a television tower at Nashville, Tennessee, southeast of the place of banding.

Catbirds are common victims at television towers and other high structures during night migration. Even long ago Gastman (1886) recorded catbirds among the casualties at an electric light tower in late September at Decatur. Catbirds comprised 3 percent of about 6,500 bird specimens picked up at television towers in central Illinois between 1955 and 1967. This is about 30 times the kill of thrashers in the same period, notwithstanding the fact that more thrashers than catbirds were seen during the fall censuses when the kills occurred. The highest kills of catbirds occurred September 20–30 (Fig. 15). This was also the period of high peaks in our fall counts (Fig. 12).

There are no data on location of the wintering grounds of Illinois catbirds.

Winter Records

The distribution of winter records of catbirds in Illinois is shown in Fig. 16. There were very few winter records prior to 1950, but more have been found in recent years as participation in the Christmas counts has increased. The frequency of occurrence during the past 25 years (1944–1968) has been only 1 percent in the north (192 censuses) and south (124 censuses) zones of the state and 3 percent in central Illinois (140 censuses).

How often catbirds actually remain through the winter in Illinois is unknown. Nor is it known how well they survive.

Food Habits

There is little information on the foods of catbirds in Illinois other than the studies of Forbes (1880) based on specimens collected in northern and central Illinois (Fig. 17). Forbes found that in May catbirds fed almost entirely on animal matter. Ants, caterpillars (Lepidoptera), crane flies (Tipulidae), ground beetles (Carabidae), and spiders were quite regularly important constituents of the diet, but beginning in June, fruits were increasingly important on into the summer (Fig. 17).

Fig. 14. — Catbird nest (not in situ) with eggs, slightly smaller than life size. The eggs, usually 3 or 4, are solid colored, rich blue-een.

nong the wild fruits, elderberries *(Sambucus cana-nsis)* were particularly favored in September but we ve seen catbirds feeding heavily on black cherries *runus serotina)* also, and, in baiting birds to photo-aph (Fig. 11), we found that catbirds showed a pref-ence for pokeweed fruit *(Phytolacca americana)* en over elderberries. Cultivated fruits were also much used, especially raspberries, blackberries, and cherries. Kinney (1868) called the catbird "the most worthless bird . . . ; eats most kinds of fruit and mutilates more than it eats, especially grapes."

Recently in northeastern Illinois Young (1968) observed catbirds preying on newly emerged adult dragonflies (Odonata). These insects seemed to be an important

TABLE 6. — Fledging success of catbirds[a] (computed by exposure-day method, Mayfield 1961).

Region	Year	May-June				July-August			
		Number		Percent Fledged		Number		Percent Fledged	
		Nests	Eggs	Nests	Eggs	Nests	Eggs	Nests	Eggs
thwest	1968	33	114	40	36	15	40	69	69
tral	1969	10	35	49	49	[b]	[b]	[b]	[b]
theast	1967	[b]	[b]	[b]	[b]	21	58	34	34

[a] Based on all active nests including those that failed during nest building and laying.
[b] No data.

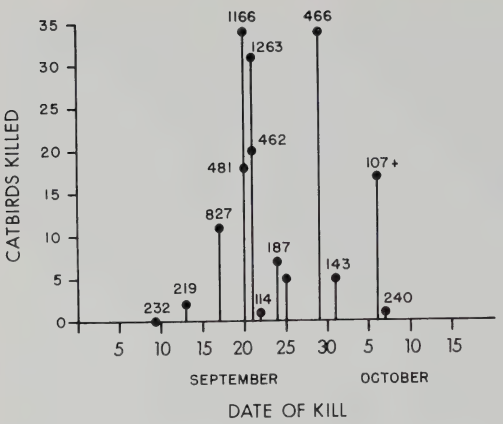


Fig. 15. — Numbers of catbirds killed at central Illinois television towers during night migration. The numbers on the graph lines indicate the total numbers of specimens picked up of all species.

Fig. 16. — Winter records for the catbird in Illinois.

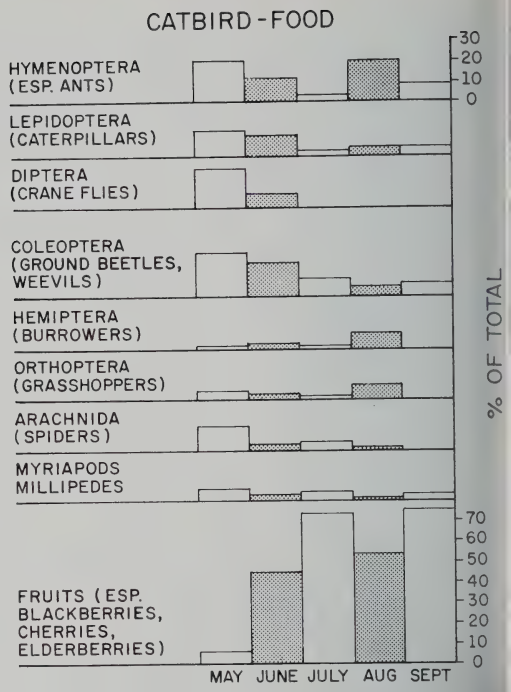


Fig. 17. — Food habits data on the catbird from the study of Forbes (1880). Percentages represent the part of the total food identified in the stomachs of a number of catbirds examined each month.

food for the birds, and at one pond the predation had a drastic effect on the dragonfly population. There are no other recent studies on the catbird's food. Our only information on the food of nestlings is from our observation that older nestlings were fed black cherries, especially in southern Illinois. There are no data on the relative availability of different foods.

Catbirds are readily attracted to feeders. Brintnal (1918) and Jackson (1905) reported catbirds eating suet, and even feeding it to fledglings. Jacques (1927) noted that catbirds were attracted to fruit, especially cu apple, and Schafer (1917) mentioned the catbird's fond ness for walnut (*Juglans* sp.) kernels.

Longevity

The oldest Illinois catbird on record was a bird banded by Bartel (1967) at Blue Island. It was at leas 6 years and 9 months of age. There have been no popula tion studies on the average life expectancy of catbirds.

Bartel (1962) found that catbirds disappeared from a Blue Island area in 1959 following an application o heptachlor. He felt that the catbird population was also

epressed the next year, perhaps reflecting the reduced ood supply following the insecticide application.

pecimen Data

In our series of 58 catbird specimens (Table 7) ved from television tower kills in central Illinois in eptember and October during the past 4 years, there are vo distinct color types showing little or no gradation. oth types are represented in all age and sex classes. ne type, presumably representing the nominate race, is arker with very dark bay crissum. The other form is ecidedly pale, especially on the belly and crissum, the issum being rufous brown.

In all respects the paler birds show the characters of e western race, *ruficrissa* (Aldrich 1946, Phillips, et al. 964), and we are tentatively considering them as that rm. There are several reasons for caution in accepting e identification. The greatest drawback is the paucity of recent comparative material in fresh fall plumage. Except for our own series, most of the catbird specimens we have seen are so old as to be almost worthless for color comparisons. We are also concerned by the high proportion (nearly 50 percent) of *ruficrissa* in our collection. Is there, in fact, such a notable migration of western birds through east-central Illinois? On the other hand Aldrich (1946) included the West Indies in the winter range of *ruficrissa*, in which case Illinois can very well be on the migration route. Also, Phillips, et al. (1964) noted that the *ruficrissa* population migrates eastward, and we now believe that many western catbirds do migrate through Illinois.

Students in other parts of the state can also shed more light on the problem by preserving large series of specimens from local tower kills. Comparative series from southern and northern Illinois should prove particularly interesting.

TABLE 7. — Weights and measurements of fall (September-October) catbird specimens killed in east-central Illinois.

e and Sex	Number of Specimens	Gross Weight (grams)		Wing Length (mm)		Tail Length (mm)		Culmen from Nares (mm)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
ult male	11	33.4–42.5	39.0	87.8–94.5	91.7	89.6–98.0	93.9	12.2–13.7	13.0
mature male	21	34.4–49.1	40.1	84.5–92.3	88.3	83.4–94.9	89.7	11.0–13.0	12.0
ult female	9	34.7–41.0	37.7	85.5–91.0	88.5	87.0–95.6	91.2	12.1–13.5	12.8
mature female	17	33.6–44.1	38.6	83.8–88.3	86.0	83.0–90.1	87.1	11.2–12.8	12.0

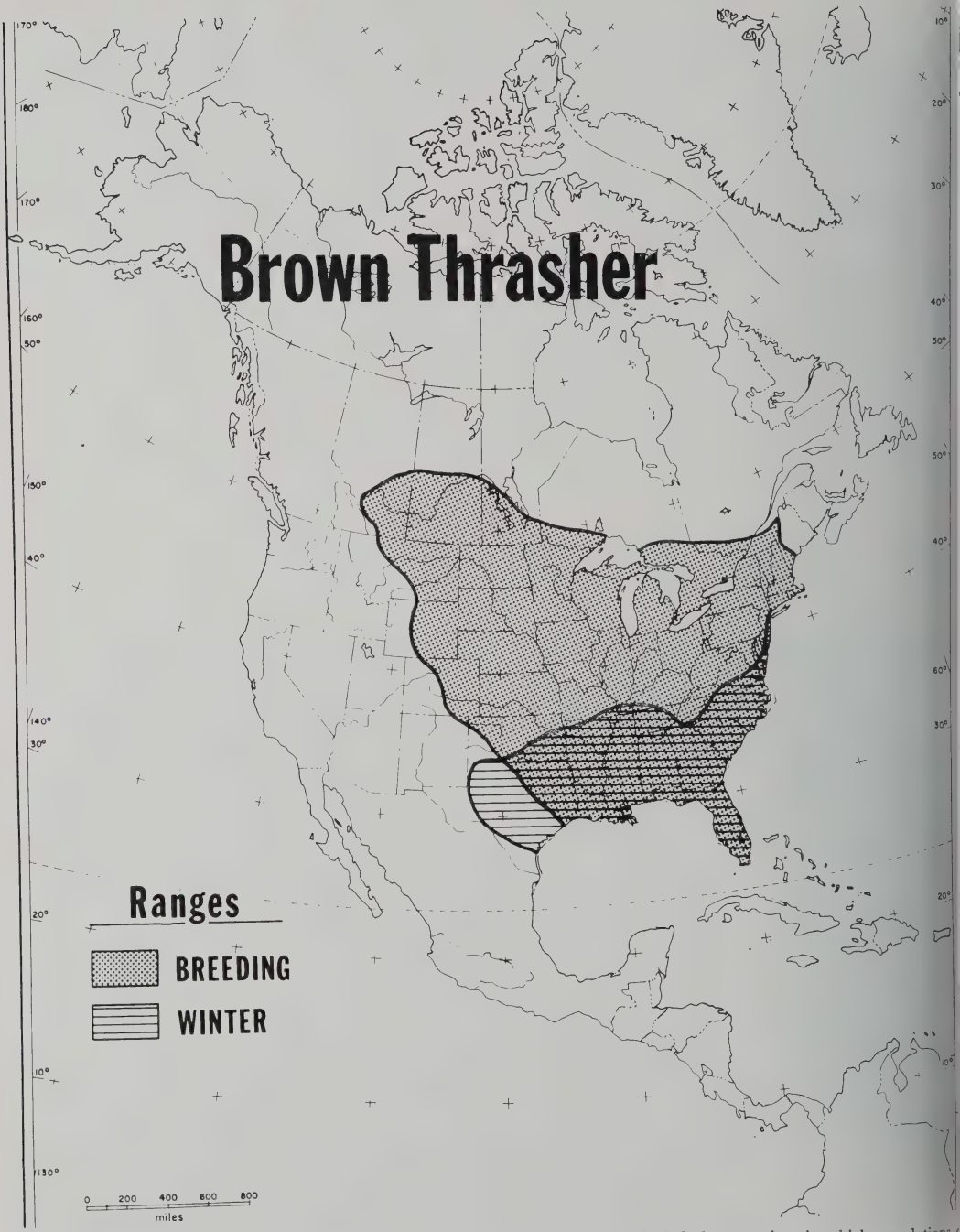
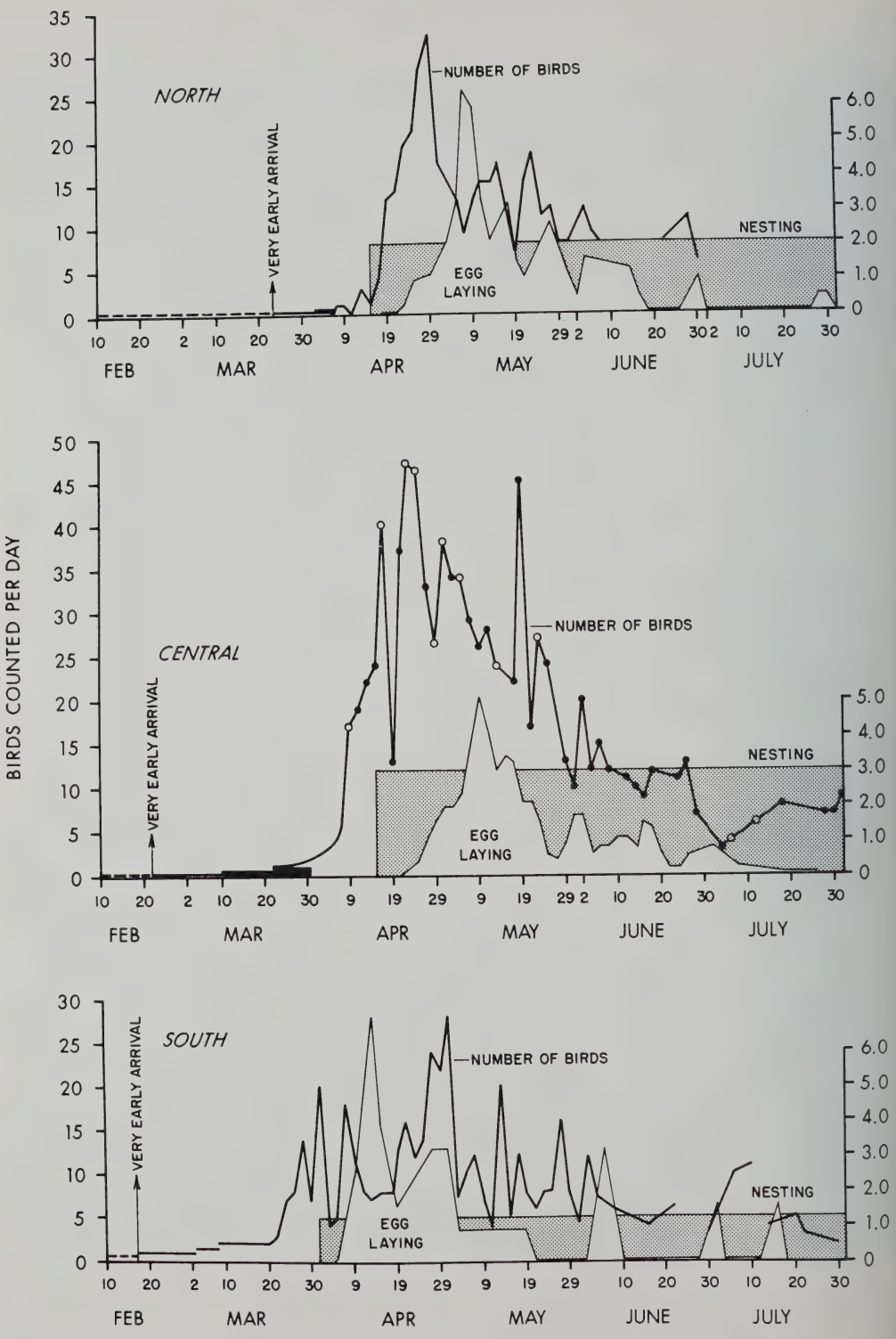
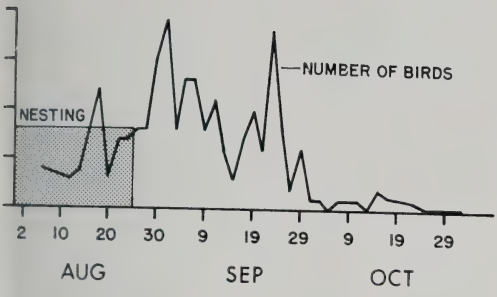
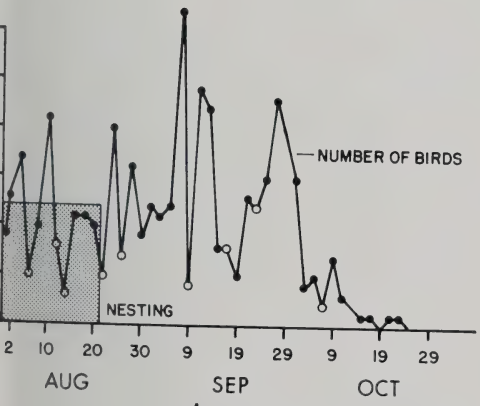


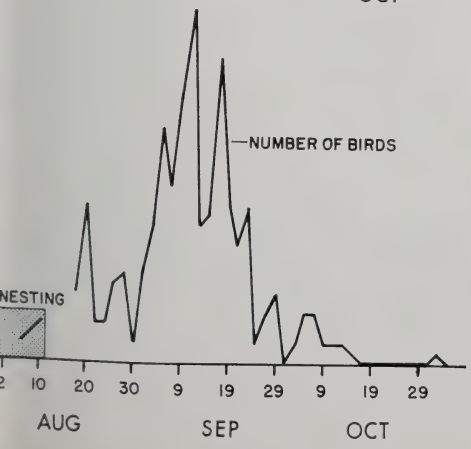
Fig. 18. — General distribution of the brown thrasher. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain, and paucity of suitable habitat.

Fig. 19. — Brown thrasher in slightly worn breeding plumage. The bird is near its nest.


NORTH
NUMBER OF BIRDS
VERY EARLY ARRIVAL
NESTING
EGG LAYING
CENTRAL
SOUTH
BIRDS COUNTED PER DAY
% OF EGGS LAID ON GIVEN DATE
FEB
MAR
APR
MAY
JUNE
JULY







BROWN THRASHER *(Toxostoma rufum)*

(Fig. 18 and 19)

Spring Migration

The onset of the thrasher's spring migration is somewhat obscured because of the thin winter population, and the paucity of birds involved in the earliest flights (Fig. 20). This early influx, which reaches southern and central Illinois in late February or early March and northern Illinois in late March, may be a different phenomenon than the larger migrations that start 2 weeks to a month later. At least the later migrations are probably nocturnal. One specimen was recovered with other night migrants on the night of May 6–7 by Brewer & Ellis (1958).

The most frequently mentioned arrival dates for southern Illinois are March 21–27 (Ridgway 1889, Cooke 1888). Our census data indicated major movements of thrashers from March 26 through most of April and May with peak numbers in late April and early May (Fig. 20).

Thrasher arrivals in central Illinois have been noted especially from March 23 to April 1, and there were marked waves from April 1 to 13 (Hess 1910, Smith 1930, and others). The 1969 census data indicated relatively large migrations throughout April and May with peak numbers in late April. The highest counts were obtained in the western study area along the Illinois River valley.

March records of thrashers in northern Illinois are unusual, and the most frequent arrival dates mentioned are April 10–17 (Abbott, et al. 1933, Kerber 1923, Gault 1901, and others), with the peak numbers following quickly in late April (Fig. 20).

There was relatively little difference in the timing of the peaks of the thrasher migration in southern, central, and northern Illinois. A noteworthy difference, however, is that in southern Illinois thrashers of the local breeding population established nests before the peak in migration, while in central and northern Illinois most nests were established after the peak (Fig. 20). This lends credence to the idea that the peak counts actually represent the passing of transients, i.e., birds enroute to places farther north. We have only one banding recovery to indicate where transient thrashers are headed in the spring. A bird banded at Urbana, April 22, 1965, was recovered the following April due north in eastern Wisconsin (Fig. 26).

Distribution

The general distribution of the brown thrasher is shown in Fig. 18. The thrasher probably nests in every

Fig. 20. — Nesting and migration seasons of the brown thrasher in different regions of the state (see Fig. 1). Spring and fall graph lines show the highest daily counts of each 2 days (left hand scale). The lines are interrupted where data have not been collected. Shaded block indicates length of the nesting season and level of adult nesting population. Circle points represent censuses in the Illinois valley; solid points represent east-central Illinois. Egg-laying graph line (right hand scale) is based on repeated searches of roadside habitat throughout the nesting season.

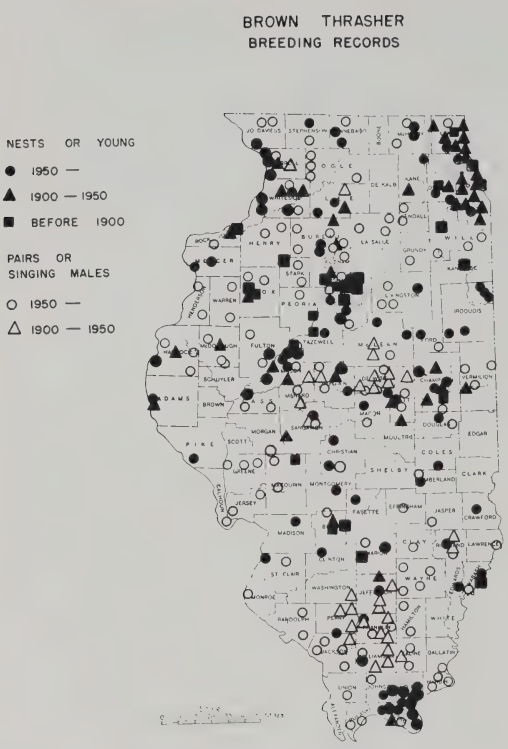


Fig. 21. — Breeding records for the brown thrasher in Illinois. Singing male records are for June only.

township in Illinois, yet published nesting records are lacking for many counties in the state (Fig. 21).

Nesting Habitats and Populations

The favorite habitats of the thrasher, judging from population densities, are hedgerows and other roadside or field edge plantings, thickets, and shrub-grown areas (Ridgway 1889, Gates 1911, Beecher 1942). The species also nests in woodlands, both natural forests and those modified by man (Beecher 1942). The thrasher is a species of the forest edge and not the forest interior (Kendeigh 1944 and others). Holmes (1950), comparing bird populations of three forest habitats in Piatt County, found no thrashers in floodplain forest or upland forest, but a density of three pairs per 100 acres in forest edge. In southern Illinois the large block forests, even the forest edges, are relatively little used by thrashers.

The thrasher is as closely tied to edge situations, for example, hedgerows, as any Illinois species. The habitats it uses most are those that are the least available (Fig. 22) and probably most endangered. Furthermore, the data on residential habitat indicate that the thrasher is not

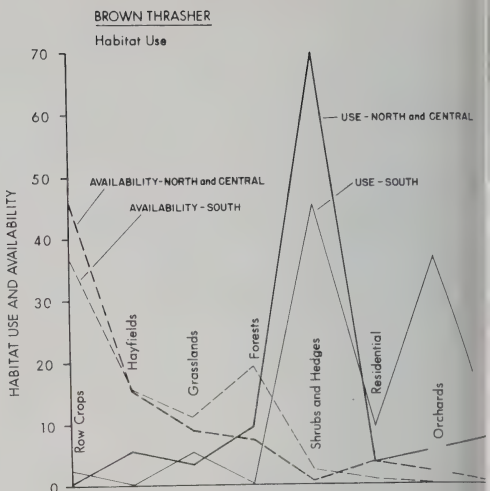


Fig. 22. — Availability of habitats for the brown thrash (and, in general, for the mimids) in relation to their use. T scale shows the percent of Illinois land (availability) in ea kind of habitat, and also the percent of the Illinois bro thrasher population (use) in each habitat.

very adaptive to man. Early in this century, thrash populations were high in human residential areas, b now they are relatively low (Graber & Graber 1963).

The most apparent requirement of the nesting habi is shrubby cover, and thorny and/or dense plants a particularly favored (Table 8). There was marked var tion in the species of plants used for nesting between t southern and northern areas of Illinois. The list is u doubtedly incomplete, and we have no data on the re tive availability of plant species used by thrashers. Lou (1891) felt that most nests in the Peoria area were plac in "hedges," i.e., osage orange. In northeastern Illin Benjamin Gault (field notes, 1885–1915) also record most thrasher nests in osage orange. Nearly all nests forest edge habitat in Piatt County were in hawtho (Allison 1947, Weise 1951). The species also nests on t ground, and Musselman (1920) recorded thrashers ne ing 2 years in a bird house with the top raised.

Population figures for the thrasher in major habit (Table 9) show marked regional variation, and so variation from year to year. There is evidence that t thrasher population in Illinois has declined greatly sin the turn of the century, especially in the south (Gra & Graber 1963).

The only data available on the size of nesting te tories of brown thrashers is for forest-edge habitat Piatt County (Allison 1947, Hensley 1948, and Re 1949). Territories averaged 1.6 acres in 1946, 2.8 1947, and 2.7 in 1948. They were larger when the popu tion was lower, and smaller when it was higher (Hens 1948).

Table 8. — Plants used by brown thrashers as nest sites excluding 212 nests found in a special study of osage orange edgerows in central Illinois).

Plants	Percent of Total Nests		
	North (116 Nests)	Central (136 Nests)	South (62 Nests)
sage orange *(Maclura pomifera)*	39	41	5
ultiflora rose *(Rosa multiflora)* + *Rosa* sp.	5	8	24
ed cedar *(Juniperus virginiana)*	1	1	31
rape *(Vitis* sp.*)*	10	5	2
oneysuckle *(Lonicera* sp.*)*	2*(shrub)*	2*(shrub)*	13*(japonica)*
rabapple and apple *(Malus* sp.*)*	4	2	3
m *(Ulmus* sp.*)*	3	1	3*(alata)*
awthorn *(Crataegus* sp.*)*	6	18	..
oseberry *(Ribes* sp.*)*	6	3	..
x-elder *(Acer negundo)*	3	2	..
ulberry *(Morus* sp.*)*	2	3	..
ac *(Syringa vulgaris)*	1	4	..
ak *(Quercus* sp.*)*	3	..	2
amble *(Rubus* sp.*)*	3	1	..
illow *(Salix* sp.*)*	1	1	..
ver birch *(Betula nigra)*	1	1	..
ssafras *(Sassafras albidum)*	..	..	5
gwood *(Cornus* sp.*)*	4	..	..
ld plum *(Prunus americana)*	..	4	..
rginia creeper *(Parthenocissus quinquefolia)*	3	..	..
ck orange *(Philadelphus* sp.*)*	..	..	3
mpet-creeper *(Campsis adicans)*	..	..	3
ckhaw *(Viburnum prunifolium)*, nd *Viburnum* sp.	2	..	..
e *(Pinus* sp.*)*	2	..	..
enbrier *(Smilax* sp.*)*	..	..	2
ersweet *(Celastrus scandens)*	..	..	2
rea *(Spiraea* sp.*)*	..	..	2
owberry *(Symphoricarpos* sp.*)*	..	1	..
zel *(Corylus americana)*	1	..	..
den-bell *(Forsythia* sp.*)*	1	..	..
uty-bush *(Kolkwitzia amabilis)*	..	1	..

sting Cycle

Banding data provided by Lyon (1921), Lincoln 927), Bartel (1942, 1943), and Jurica, et al. (1959, 60, 1962) show that at least some of both juvenile and lt thrashers return to the same summer home after migration, but there are no quantitative data on year-ear homing and survival.

Courtship and territorial behavior by thrashers must in almost immediately after the birds arrive from the tering grounds (Fig. 20). Several authors refer to the that the males arrive singing. To Ridgway (1889), o most listeners, the thrasher was a superior songster. song, sweet but loud, is often delivered from the top tree, and characteristically has fewer repetitious notes ually not more than three) than the song of the kingbird. Ridgway (1874), who spent many years in shington, D.C., felt that the thrashers of southern ois sang more vigorously than those in the East. In northeastern Illinois Gault (1901) noted that thrashers begin to grow listless during June, and the singing is much reduced. In addition to the loud song, there is a very soft, more complex whisper song, usually uttered while the bird is low in a shrub or thicket, and probably heard most often in the early part of the nesting season (Coffin 1915, Schafer 1916). During much of the nesting season, and in late summer especially, an observer is more likely to hear the loud "smack" alarm call than the song.

The nesting season, the period between the onset of nest building and the fledging of the last young of the year, lasts from about April 1 to August 12 in southern Illinois, from April 15 to August 21 in the central zone, and April 15 to August 25 in the north (Fig. 20). In terms of what most of the thrasher population does, however, the nesting season is much shorter than these dates indicate. For example, most of the egg production occurs in April in southern Illinois, and in May in the central and north (Fig. 23).

The minimum time required from the onset of nest-building to the fledging of (three) young was 32 days for a nest in Ford County. In this case nest construction required 4 days, egg-laying 3 days, incubation 13 days, and the nestling stage 12 days. One nest we observed which looked complete when it was found went 13 days before the clutch was started. Incubation periods were nearly always 12½–13 days, but one clutch in the north took 14 days. One female incubated eggs with dead embryos at least 16 days but abandoned by the 22nd day. Young usually fledged in 12 or 13 days, but one stayed at least 14 days.

Data on the plants used for nest sites are presented in Table 8. Most thrasher nests are found 2–5 feet above ground in northern and central Illinois, and 3–6 feet in the south (Fig. 24). About 5 percent of the nests recorded in central and northern Illinois have been ground nests, but there are apparently no such records for southern Illinois. Nearly all ground nests have been near shrubby cover, frequently at the bases of shrubs, but Kennicott (1853–1854) mentions finding several nests under fences in the prairie. The height of nests in osage orange trees in Ford County tended to vary with the season as in the case of the mockingbird in the south, with the early nests being lower (April-May: 3 feet; June-July: 5 feet).

Brown thrashers lay their eggs early in the morning (Silloway 1906) and on consecutive days. Most April-May nests receive four eggs and most June-July nests have three eggs (Table 10). Clutches of five eggs are decidedly more common in the northern region of the state than in the central or south (Table 11). In some years large clutches are particularly prevalent, e.g., in 1933 (Blocher 1933) and 1914–1915 (Sanborn & Goelitz 1915), but the cause of this annual variation is unknown. True two-egg clutches are apparently very rare; most nests found with two eggs have probably lost eggs one way or another. One nest we observed received seven eggs from two females, in two laying sequences — a four-egg clutch laid May 13–16 and a three-egg clutch laid May

TABLE 9. — Breeding populations of brown thrashers in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Hedgerows	9	144	1957	Nest	Ford (C)	Graber, unpubl. data
	8	189	1957–1958	Strip	Central	Graber & Graber 1963
Edge shrubbery	11	61	1957–1958	Strip	North	Graber & Graber 1963
	13	68			Central	
	20	76			South	
Thickets	7	113	1937	Nest	Lake (N)	Beecher 1942
	13	23	1950	Nest	Jackson (S)	Brewer & Hardy 1950
Block shrub areas	32	28	1957–1958	Strip	North	Graber & Graber 1963
	49	12			Central	
	107	2			South	
	60	2	1949	Nest	Richland (S)	Stine 1949
Early shrub	. .	24	1966	Nest	Vermilion (C)	Karr 1968
Late shrub	. .	28	1966			
Orchard	78	12	1957–1958	Strip	South	Graber & Graber 1963
Second growth or cut-over woods	15	86	1937	Nest	Rock Island (N)	Fawks 1937
	15	57	1938			Fawks 1938
	56	36	1941	Nest	Sangamon (C)	Robertson 1941
	56	39	1942			Robertson 1942
	56	25	1944			Robertson 1944
	46	14	1948			Robertson & Snyder 1948
Virgin floodplain forest	77	2	1948	Nest	Sangamon (C)	Snyder, et al. 1948
Grazed bottomland	93	2	1955	Nest	Macon (C)	Chaniot & Kirby 1955
Forest (all types including edge)	177	1	1957–1958	Strip	North	Graber & Graber 1963
	214	8			Central	
	340	0			South	
	27	15	1937	Nest	Lake (N)	Beecher 1942
	24	+[b]	1967	Nest	Hancock (C)	Franks & Martin 1967
Forest edge	55	0–2	1927–1948	Nest	Champaign (C)	Kendeigh 1944, 1948
	55	(0–8 birds/mile)	1949–1968	Nest	Champaign (C)	Kendeigh & Fawver 1949 Kendeigh & Forsyth 1959 and Kendeigh & Barnett 1968
Modified woodland	28	7	1937	Nest	Lake (N)	Beecher 1942
Parkland estates	100	18	1915	Nest	Cook (N)	Eifrig 1915
Residential areas	160	1	1957–1958	Strip	North	Graber & Graber 1963
	75	4			Central	
	98	3			South	
Swampy prairie	67	9	1941	Nest	Sangamon (C)	Robertson 1941

[a] All figures were converted to read birds per 100 acres or birds per mile of edge (number of territorial males or nests × 2).
[b] Less than one.

22–24. Eggs in the first clutch never developed embryos, but the second clutch was successful.

Cowbird parasitism is probably not a significant problem for the thrasher, although the incidence may be high at times. Miller (1955) reported two nests parasitized (of seven found) in farmland in Champaign County, and Hensley (1948) reported one parasitized (of two found) in forest edge habitat of Piatt County. In the northern region only 2 percent of 83 nests that received full clutches were parasitized. The incidence for all central Illinois nests with adequate data also was 2 percent. We have data on only 39 nests for southern Illinois, 1 of which was parasitized. Parasitized nests fledged thrashers but not cowbirds, although in one nest a cowbird survived 6 days. Silloway, in a typed manuscript in 1924 entitled "Birds of the Peoria Parks," and Hensley (1948) reported the selective removal of cowbird eggs from thrasher nests, presumably by the adult thrasher. The incidence of para sitism was higher for the thrasher than for the other tw mimids, and thrasher eggs more closely resemble cowbir eggs (Fig. 25).

Juvenile thrashers may be seen out of the nest as earl as April 27 in southern Illinois (Ridgway 1925), and Ma 18 in central and northern Illinois.

Nesting Success

The laying curve for the thrasher (Fig. 23) sugges that most thrashers are not double brooded. Because parasitism, predation, infertility, and other causes, the appear to have trouble enough producing one broo (Table 12), and we suspect that most June-July nes represent repeated nestings after earlier failures. In nes that we observed, only about a third of the eggs laye produced fledglings (Table 12). These data refer t

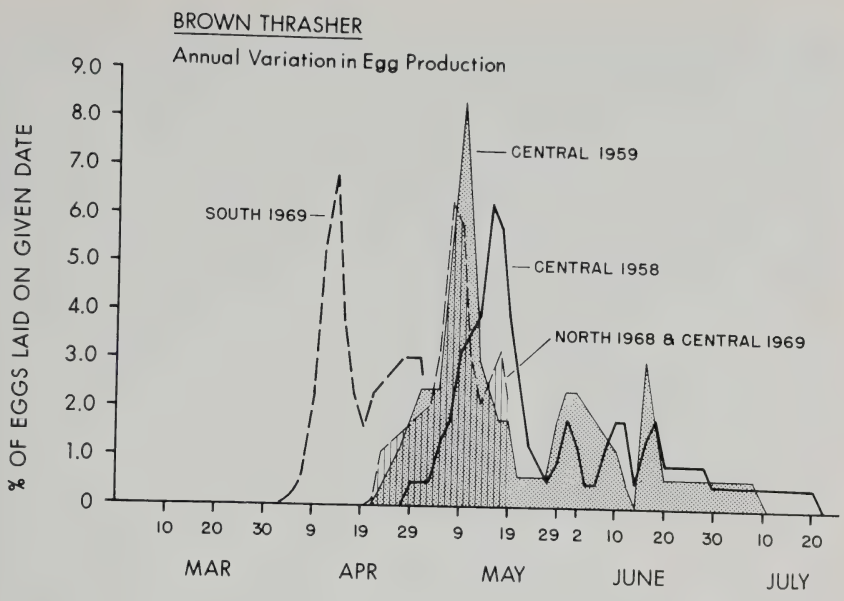


Fig. 23. — Annual and regional variation in egg production by brown thrashers. Note especially the very early nesting cycle in southern Illinois. Lines are interrupted where data have been collected.

ashers in hedgerows or similar linear habitats, and ting success may be very different in other situations. Although in general there was little difference in nest rival between regions (Table 12), our observations indicate that the nesting problems are actually very different n place to place. For example, in the Ford County ulation the incidence of "infertility," i.e., no embryonic elopment following incubation, was 11 percent in eggs n full clutches, but it was only 1 percent in our sample ggs in northern Illinois, and 3 percent in the southern on sample. In another 3–5 percent of the eggs (all ons), the embryos died before hatching. In the ples of central and southern Illinois nests, we found w nests in which the young birds perished, not from lation but from some other cause, possibly low temtures. Such nestlings accounted for about 3 percent e eggs in nests with full clutches.

Our judgment on the causes of mortality in the reder (the majority) of nest failures is based on mstantial evidence. We suspect that in the northern central study areas, the fox squirrel *(Sciurus niger)* is nificant predator on thrasher nests. We have never

ABLE 10. — Seasonal variation in clutch sizes of brown hers in Illinois.

nths	Total Nests	Percent of Nests by Clutch Size			
		5 Eggs	4 Eggs	3 Eggs	2 Eggs
May	203	6	68	25	1
July	64	1	34	63	1

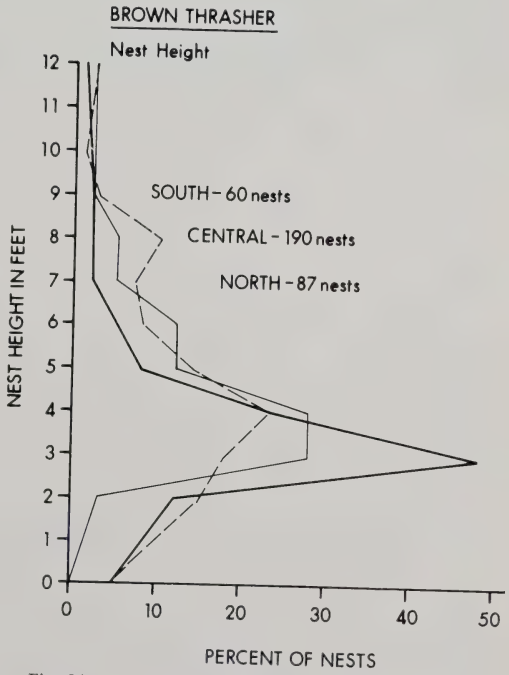


Fig. 24. — Percentages of brown thrasher nests at different heights in roadside habitats in different regions of the state. Heavy solid line represents central, light solid line southern, and dotted line northern Illinois.

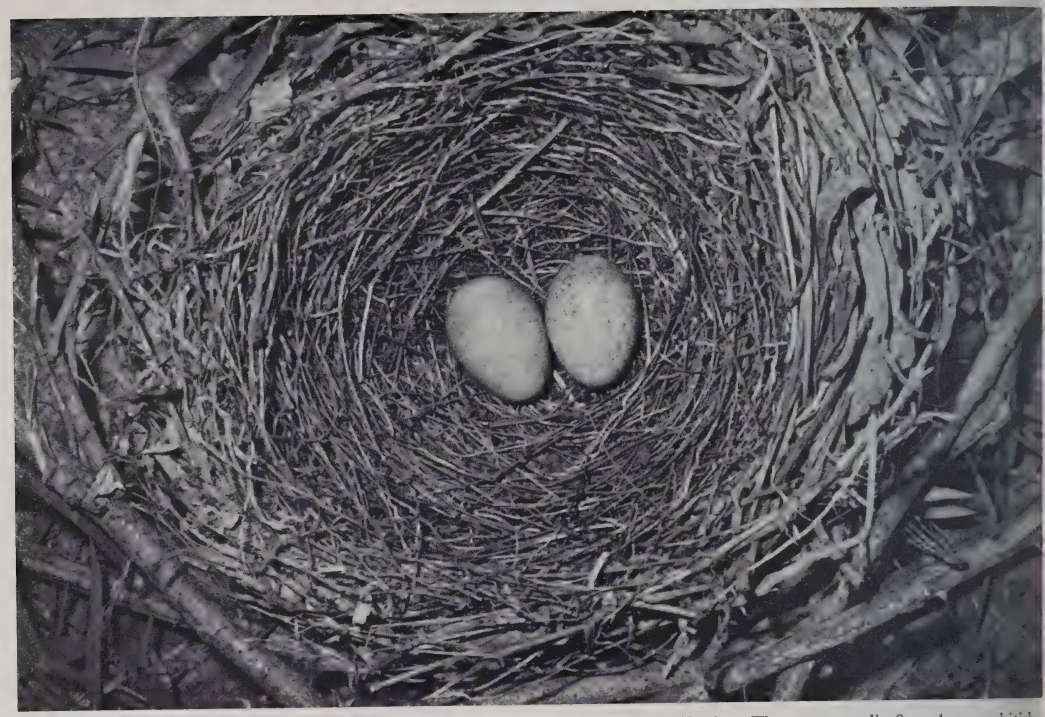


Fig. 25. — Brown thrasher nest (not in situ) with eggs, slightly smaller than life size. The eggs, usually 3 or 4, are whitish pale green, speckled with reddish brown.

witnessed the actual predation, but have found squirrels in nests that were recently active. In these instances the squirrel had placed green leaves in the nest and was using it as a diurnal resting place. In southern Illinois, the predator we saw at or near nests most frequently was the black rat snake. In north-central Illinois we once saw a fox snake *(Elaphe vulpina)* eating thrasher eggs. However, we have too little data on the identity and populations of nest predators to understand their effect. Like mockingbirds and other species, thrashers will vigorously attack even large snakes but without much effect. An interesting account of such an attack is given by Nilsson (1957).

Fall Migration

By mid-August a few thrashers appear to have com pleted the molt, but most are still ragged and moltin By early September most of them are in fresh plumage.

There is wide discrepancy in the departure dates f this species recorded in the literature, ranging from mi August to late November. Even in July we have not the seeming disappearance of thrashers from a local po ulation. We have no idea where these birds go, or eve with any certainty, that they actually go, but the obse vations indicate a definite change in the birds' behavior

Most of the departure dates recorded in the literatu

Table 11. — Clutch sizes of brown thrashers in different regions of Illinois.

Region	Months, Years	Total Number of Nests	Average Clutch	Percent of Nests by Clutch Size			
				5 Eggs	4 Eggs	3 Eggs	2 Eggs
North Central	April-May, 1968	56[a]	4.1	20	68	12	0
	April-May, 1958	52	3.7	0	71	29	0
	April-May, 1959	36	3.7	0	69	31	0
	April-May, 1968–1969	117	3.7	1	72	27	0
South	April-May, 1967	30	3.6	3	57	37	3

[a] Includes records from literature, where complete data were provided.

Table 12. — Fledging success of brown thrashers (computed by exposure-day method, Mayfield 1961).

Region	Year	April-May				June-July			
		Number		Percent Fledged		Number		Percent Fledged	
		Nests	Eggs	Nests	Eggs	Nests	Eggs	Nests	Eggs
rthwest	1968	34	124	25[a]	20	17	48	46	38
st Central	1958	55	198	41	34	29	96	33	30
	1959	40	148	48	38	24	67	60	53
utheast	1967	34	119	44	42	12	36	29	29

[a] Success exceptionally low because of a number of nests lost in a very severe hailstorm.

e in September and October for northern and central nois. There are few records for the southern zone. ır census data (Fig. 20) show the onset of apparent ɔulation changes in mid-August in central and northern nois, and in late August in the southern part of the te. The highest migrant populations occur throughout ɔtember in all regions, falling fast in early October ɔrth and central) or late September (south). There ɔears to be a sparse but fairly regular trickle of migra- ı throughout November, but these birds may be the ıter residents.

The thrasher is a surprisingly infrequent victim among migrants killed at television towers in Illinois in view he number of thrashers seen on the censuses and the mber of catbirds killed at these towers. In a sample of ıy thousands of birds picked up at central Illinois ers, thrashers comprise only one-tenth of 1 percent he total.

As in the case of the catbird, we have never heard a ɔgnizable thrasher call during the hundreds of hours ve spent listening to the night calls of migrants.

As in the spring, fall numbers of thrashers were highest entral Illinois, and lowest in the southern region. De- e an expected population increase from spring to fall, fall counts of thrashers were never as high as the ıg counts. For the state, in general, we saw about thrashers in the spring to one in the fall, and in -central Illinois the discrepancy was especially great ing: five; fall: one).

There are only a few published recovery records for shers banded in Illinois (Lincoln 1927, Bartel 1945). ter recoveries are from Mississippi, Louisiana, and ıern Arkansas, about 600–700 miles south or slightly of south of the place of banding (Fig. 26). Two ially interesting recoveries were from birds banded stlings from the same nest by Bartel (1945) at Blue d in May, 1937. One was found at Baton Rouge, siana, November 7, 1937, and the other was shot at sett, Arkansas, January 15, 1938.

er Records

ı the past several years, thrashers have been recorded where in the state every winter (Fig. 27). Prior to the Audubon Christmas count coverage was poor ıse the number of observers was relatively small, especially in southern Illinois. Thrashers were recorded on only about 2 percent of all Christmas counts in northern Illinois, and 4 percent of the counts in the central zone (Fig. 28). With increasing coverage after 1940 the frequency of occurrence has been generally increasing, even out of proportion to the number of ob-

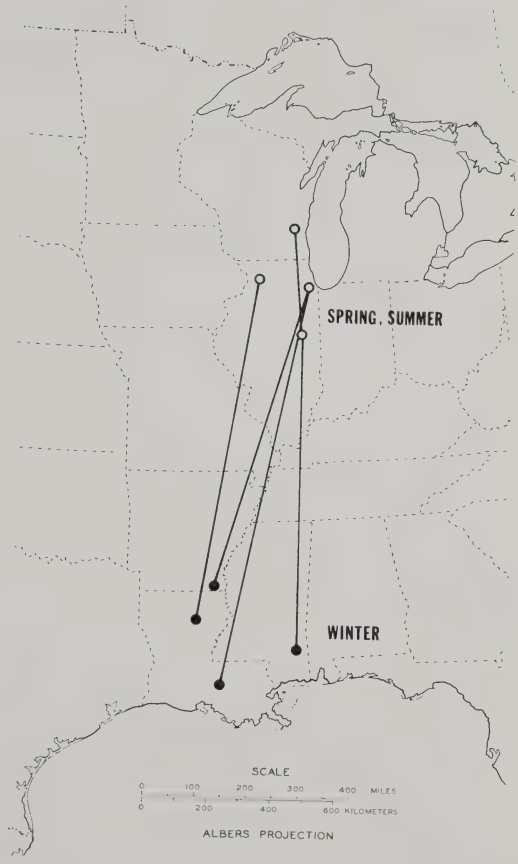


Fig. 26. — Recovery records of brown thrashers banded in Illinois. The only spring recovery was due north in Wisconsin.

servers. Thus we feel that thrashers are actually wintering in Illinois in greater numbers now than in prior decades.

Food Habits

Very little information is available on the food of the thrasher in Illinois other than that from Forbes (1879, 1880), based on his studies of specimens from northern and central Illinois (Fig. 29). There is no information on the thrasher's food in southern Illinois, or on what they feed their young, and it is obvious that we need expanded and comparative modern-day studies in this area.

The thrasher's food habits reflect seasonal variations in the availability of foods, and a large amount of ground foraging. Beetles in general comprised an important part of the thrasher's spring diet. In Lake County, Coale (1910) found thrashers attracted to an abundant supply of earthworms at bare places on a road in April. Forbes' (1880) studies showed seeds and grain, especially corn, to be important in the April diet. From June on through the summer, fruit became more important in the diet, and thrashers, like catbirds, were a source of irritation to many old-time orchardists (Kinney 1868). We have seen thrashers feeding on pokeberries in September and on barberries (*Berberis* sp.) in October-November.

A number of writers have commented on the thrasher's behavior at bird feeders. Though shyer than the catbird (Jacques 1927), thrashers do visit feeding stations, and in summer bring their young. Ridgway (1918, 1923) noted the thrasher's fondness for nutmeats, including cracked black walnuts *(Juglans nigra),* for her birds at Olney. Thrashers visiting a Cook County feeder in winter and spring ate only nutmeats and sunflower seeds (Fisher & Fisher 1941). Thrashers are also attracted to bird baths, especially ground pools.

Longevity

The oldest Illinois thrasher on record was a bird banded by Musselman (1958) at Quincy, July 5, 1950, and recaptured at the same place April 27, 1958, nearly 8 years later. Bartel (1967) recovered one of his thrashe 4 years after banding it. There are no data on averag longevity for any Illinois population.

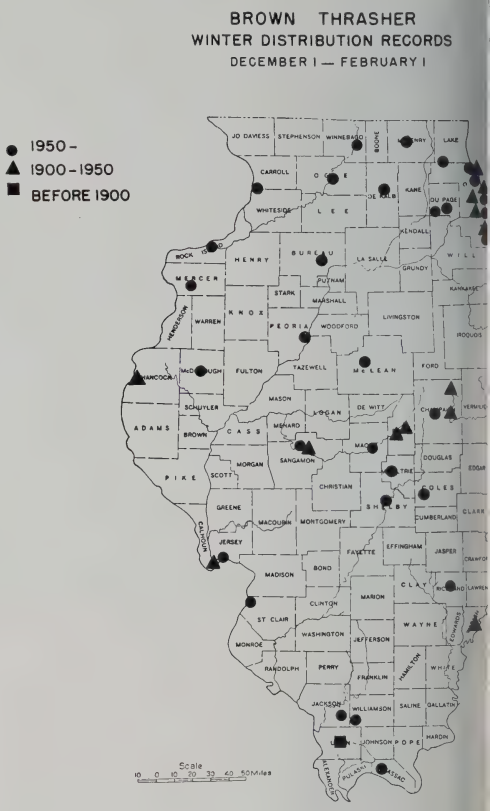


Fig. 27. — Brown thrasher winter records in Illinois.

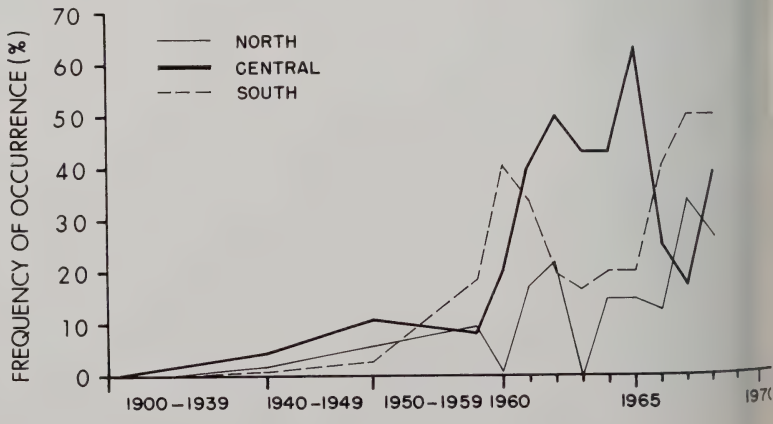
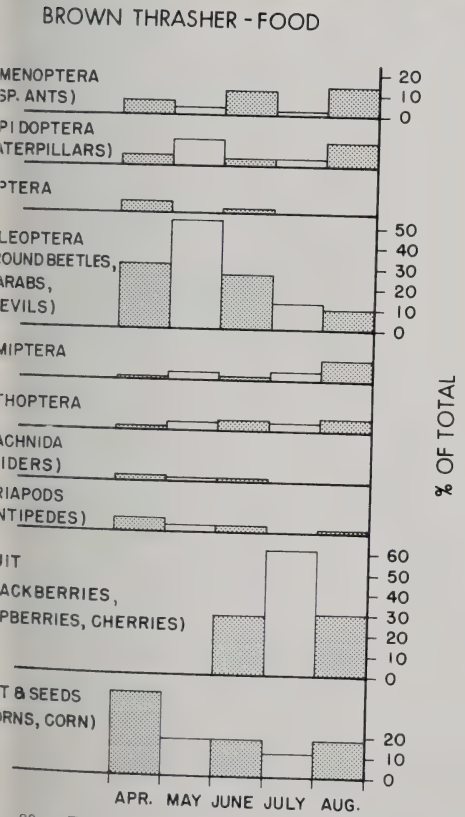


Fig. 28. — Variation in the frequency of sightings of brown thrashers on the Audubon Christmas counts for different periods of years and different regions of Illinois (annual variation after 1959).



g. 29. — Food habits data on the brown thrasher from udy of Forbes (1880). Percentages represent the part of tal food identified in the stomachs of a number of thrash- amined each month.

On the whole field of diseases and parasites there is but one paper (Sachs 1953). It gave the incidence of blood parasites in a sample of 23 thrashers, as follows: *Haemoproteus*–17 positive, *Trypanosoma*–2 positive, *Leucocytozoon*–1 positive.

Bartel (1960, 1962) recorded the thrasher among the species which disappeared from an area in Cook County that was sprayed with heptachlor epoxide. Scott, et al. (1959) also reported a notable kill of thrashers in Iroquois County following aerial application of dieldrin at the rate of 3 pounds per acre.

Because thrashers frequent roadside vegetation, they would seem to be susceptible to problems with modern traffic. There are no recent studies, but Flint (1934–1935) and Starrett (1938) provided data on the question for an era when traffic was thinner and slower. The highest kill was in east-central Illinois in 1930 when Flint (1934–1935) found a thrasher for every 125 miles driven, and thrashers comprised about 2 percent of all the birds killed by moving vehicles.

SAGE THRASHER *(Oreoscoptes montanus)*

There have been at least two reports of this western species in Illinois, a May sight record of questionable validity for Lincoln Park, Chicago (see Clark & Nice, 1950:31), and a very carefully documented and valid record of a bird at Winnetka in winter, 1969–70. The bird was discovered and identified independently by Mrs. Irene Binford and Mrs. Kenneth McKeown. The thrasher was also studied closely by Dr. Laurence C. Binford, Charles T. Clark, Robert P. Russell, and many other observers, and was also photographed. The bird visited feeding stations in Winnetka, and was present from at least December 26, 1969 to March 8, 1970.

Such records of birds, apparently way out of range, are inconsequential to the ecology of Illinois, but they are, nonetheless, always exciting to the student of birds.

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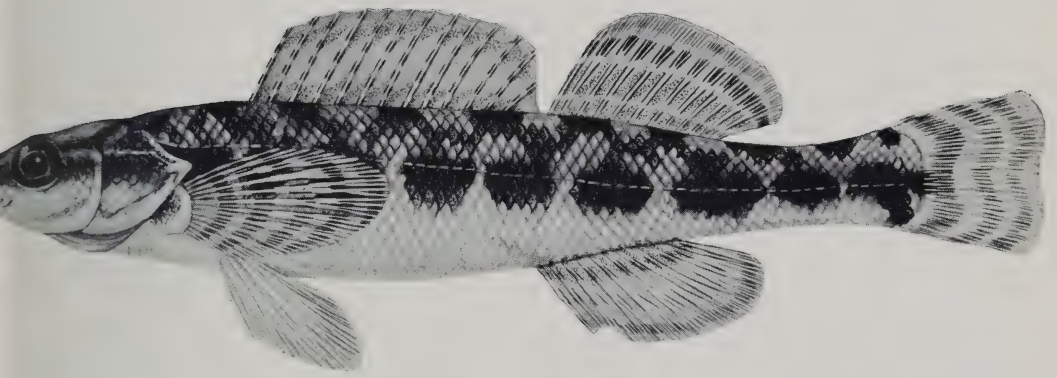
THE LIFE HISTORY OF THE DUSKY DARTER, *PERCINA SCIERA*, IN THE EMBARRAS RIVER, ILLINOIS

Lawrence M. Page
Philip W. Smith



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THE LIFE HISTORY OF THE DUSKY DARTER, *PERCINA SCIERA*, IN THE EMBARRAS RIVER, ILLINOIS

Lawrence M. Page and Philip W. Smith

THERE ARE OVER 100 DESCRIBED SPECIES of darters, which represent marked degrees of adaptation and show considerable variation in ecological and reproductive characteristics. A few species have been studied in detail, and certain aspects of the life histories of several have been investigated (see Literature Cited sections in Winn 1958*a* and Braasch & Smith 1967), but for most of them ecological information is limited chiefly to observations on their habitats in different parts of their ranges. Among the latter are the species in the subgenus *Hadropterus* of *Percina,* for which habitat requirements have been recently described (Suttkus & Ramsey 1967) but for which reproductive habits, growth, diet, and demographic parameters remain virtually unknown.

The subgenus *Hadropterus* included only *nigrofasciatus* Agassiz, 1854, and *scierus* Swain, 1883, until the recent descriptions of *lenticula* Richards & Knapp, 1964, and *aurolineata* Suttkus & Ramsey, 1967. Three of the species are restricted to the Gulf and Atlantic coast drainages; the fourth *(sciera)* is more widely distributed and is the subject of the present study.

The dusky darter was described as *Hadropterus scierus* from Bean Blossom Creek, Monroe Co., Indiana (Swain 1884:252) and, except for brief assignments to the genera *Serraria* and *Etheostoma,* was so known until Bailey, Winn, & Smith (1954:140) reduced the number of darter genera to three and relegated *Hadropterus* to subgeneric rank. Currently, the species is regarded as consisting of two subspecies, the northern dusky darter *(Percina s. sciera)* and the Guadalupe River dusky darter (*P. s. apristis* Hubbs, 1954), an endemic in the Guadalupe River system of Texas.

Percina sciera (cover illustration) is a large darter, with the adults ranging from 2 to 4 and occasionally 5 inches in total length. The adult is light olive-green dorsally, with a pattern of black or brown markings, and nearly white below. A dark band extending around the snout, through the eye, and across the opercle connects to a broken lateral band of 7–12 large, dusky, oblong blotches on each side. The latter alternate with 7–10 dark blotches, which cross the midline of the back. Three vertical dark blotches on the caudal fin base form a distinctive, partially fused bar. A dark teardrop is usually lacking. The fins are nearly transparent but have small pigment spots along the spines and rays, which give the appearance of faint bars.

The male differs from the female in having a midventral row of large and strongly toothed scales and a smaller and less rounded genital pore.

The young of *P. sciera* are distinguishable from the young of the superficially similar *P. maculata* and other species of *Percina* in the Wabash drainage by the distinctive fused blotches on the base of the caudal fin.

The dusky darter occurs from the Elk River of West Virginia (Richards & Knapp 1964:700), Tennessee River system of Kentucky and Tennessee, and the Black Warrior-Tombigbee system in Alabama southward to the Gulf Coast (Suttkus & Ramsey 1967:138) and westward through Mississippi and Louisiana to central Texas, southeastern Oklahoma, and southeastern Missouri (Trautman 1957:535). Its range extends northward to eastern Illinois, throughout most of Indiana with the northernmost record in the upper Tippecanoe River (Gerking 1945:85), and into the Scioto River drainage of south-central Ohio (Trautman 1957:535). In Illinois the species is restricted to the Ohio-Wabash drainage, and it is common only in the Embarras River and Middle Fork of the Vermilion River and their tributaries (Fig. 1).

We are indebted to Raymond T. Schaaf, Hartley F. Hutchins, Dorothy M. Smith, Norman D. Penny, and the late Robert L. Hass for aid with field work; to our associates Donald W. Webb, John D. Unzicker, Milton W. Sanderson, and Herbert H. Ross for helping with identifications of arthropod fragments in the darter stomachs; to Marvin C. Meyer, University of Maine, for identifying a leech parasite; to Harmon F. Smith, Illinois State Water Survey, for providing data on water chemistry of the Embarras River. We are grateful to Richard M. Sheets, Survey technical illustrator, for preparing the illustrations, except those of the darter which were done by Alice Ann Prickett, University of Illinois School of Life Sciences; to Wilmer D. Zehr, Survey photographer, for the photographs; to our colleagues W. C. Childers and J. A. Tranquilli for temporary use of one of their aquaria and R. W. Larimore for lending us a 30-foot electric seine and 115-v generator.

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COVER ILLUSTRATION: Adult female *Percina sciera sciera* collected in October in the Middle Fork, Vermilion County, Illinois. From a watercolor by Mrs. Alice Ann Prickett.

The manuscript was edited by O. F. Glissendorf, :chnical editor at the Survey. Edward C. Raney, ornell University, served as special guest reviewer.

THE STUDY AREA

The area selected for study was the middle Em-arras River in the vicinity of Greenup, Cumberland o., Illinois. Less disturbed than most other local reams, the Embarras supports an exceptionally large number (14) of darter species, of which *P. sciera* is the most abundant.

The Embarras River, a tributary of the Wabash, has its headwaters in Champaign County and meanders southward through rich farmland on Wisconsin glacial till until it cuts through the Shelbyville Moraine near Charleston in Coles County. For several miles downstream from Charleston the river has deposited large quantities of glacial gravel from the thick morainal deposits. Near Newton in Jasper County it veers

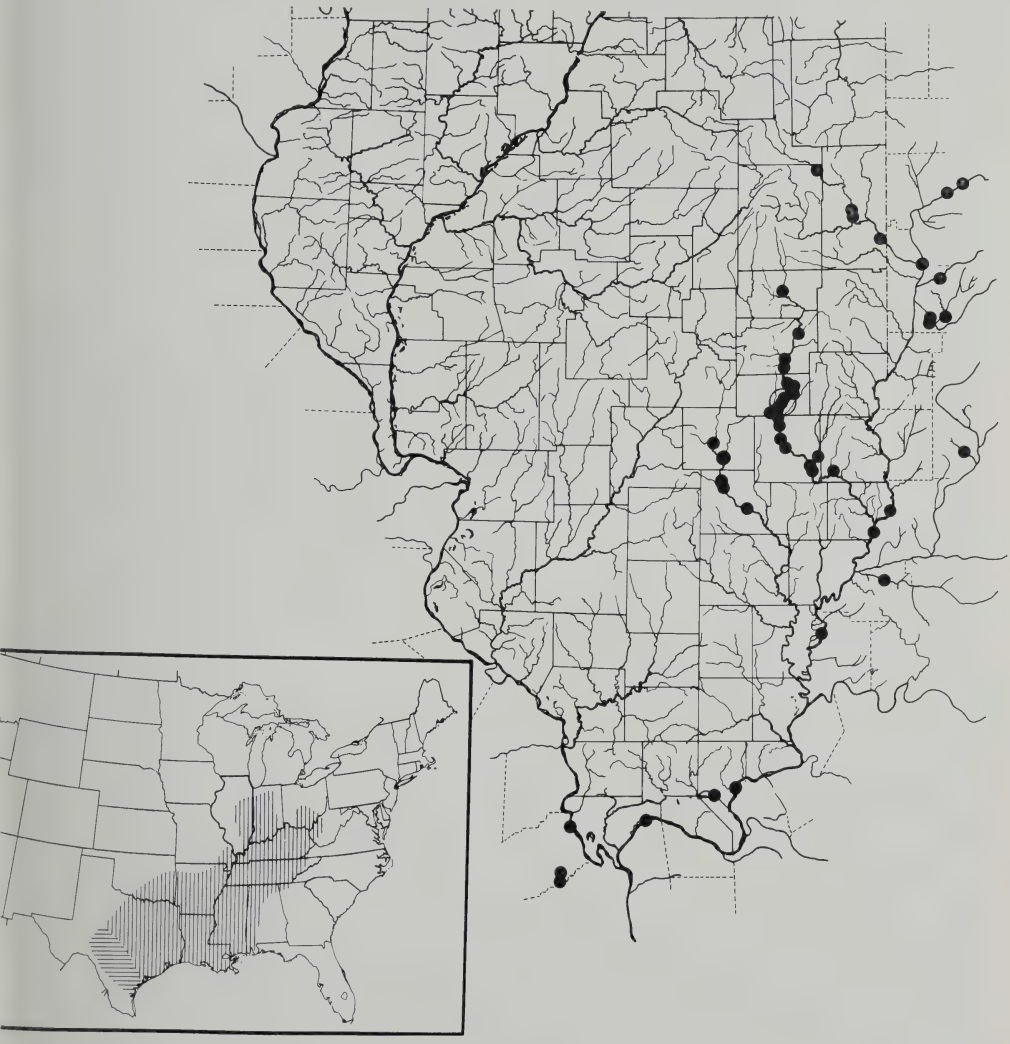

Fig. 1. — Distribution of *Percina sciera* in Illinois and adjacent Indiana and Missouri and the total range (inset) of the es. Some of the Indiana records are from Gerking (1945:85). On the Illinois map the study area is encircled (at heaviest r of dots); on the inset map vertical hatching represents the range of *P. s. sciera*, horizontal hatching that of *P. s. apristis*.

toward the southeast and flows over a bed of predominantly sand and Illinoian clays. The river empties into the Wabash River near Billett, Lawrence County, having drained about 2,400 square miles in its approximately 180-mile course through eastern Illinois.

Chemical measurements taken in the Embarras River at Camargo in Douglas County from October 1966, to April, 1968, by the Illinois State Water Survey

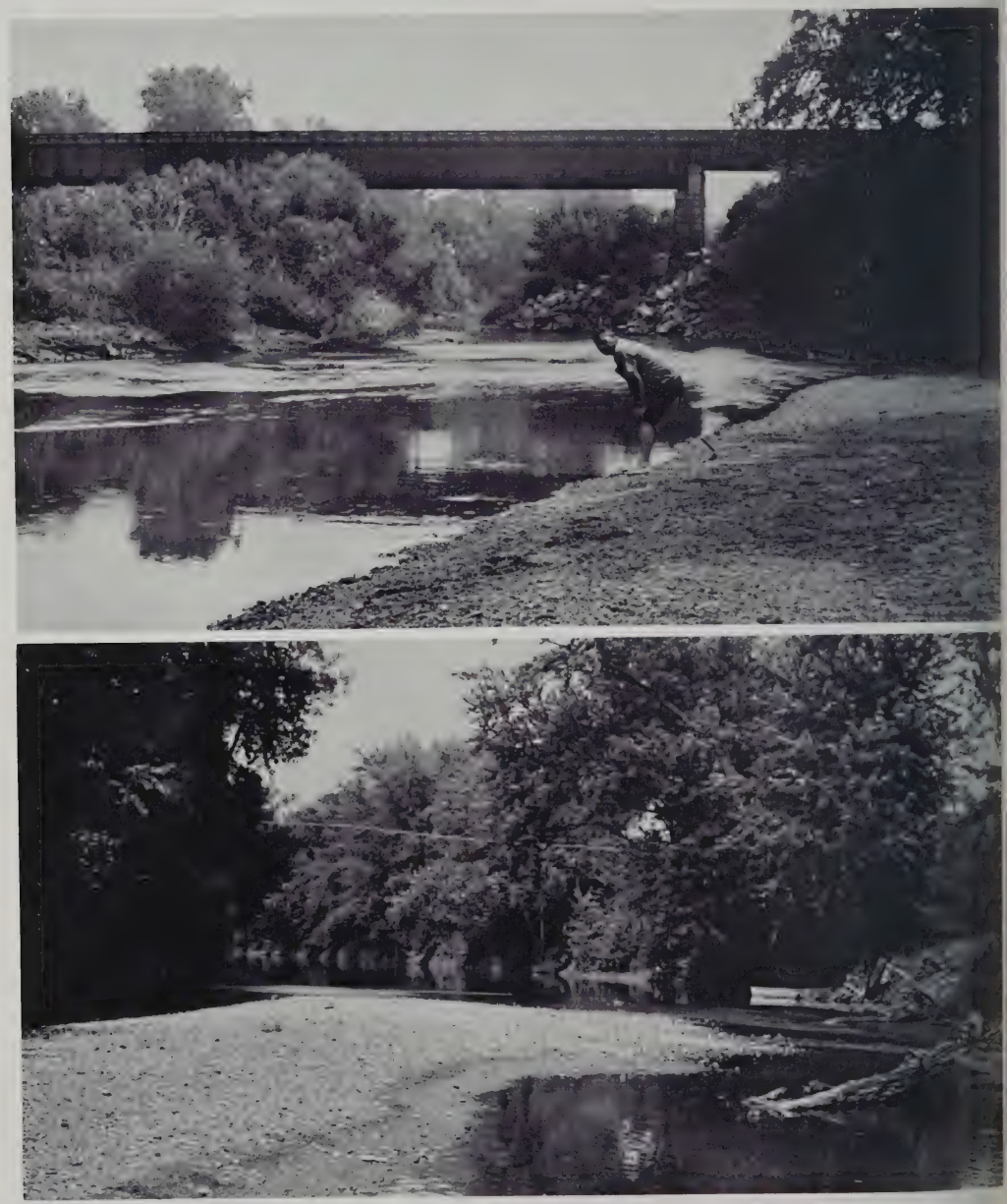

Fig. 2. — Two stations in the study area: Embarras River 1 mile west (top) and 3 miles southwest (bottom) of Greenup, Cumberland County, Illinois.

nd made available through the courtesy of Harman F. mith, indicated that the water quality was unusually igh and pollution was minimal. Average chemical alues were: total phosphates 1.2 ppm, nitrates 25 pm, sulfates 69.7 ppm, and ammonium compounds .1 ppm. The alkalinity averaged 199 ppm, hardness 85 ppm, and total dissolved minerals 376 ppm. Turidity varied during this period from 2 ppm to 138 ppm.

In the vicinity of the study area the stream could e classed as a small to medium-sized river. During ow water stages the channel was only 15 to 30 feet ide and in riffle areas barely a foot in depth, although here were some deep pools at bridge sites and at brupt bends in the river. During flood stages the oodplain was inundated, and the river was almost 1 ile wide.

The study area consisted of a 5-mile stretch of the ver (the encircled area in Fig. 1) and several nearby ocations, which were sampled when the main stations ere inaccessible because of high water. One of the rincipal sites (Fig. 2, top), one mile west of Greenup, ad a variety of habitats — gravel bars and gravelly aceways, sand bars and sandy raceways, a rubble riffle, nd several silt-bottomed pools. Another site (Fig. 2, ottom), 3 miles southwest of Greenup, was similar but ad more extensive stretches of sand bottom and lacked ubble and strong riffle areas.

METHODS

A total of 37 collecting trips was made to the study rea between August 4, 1967, and July 1, 1969. Inially various habitats were sampled to determine habitat references; later efforts were concentrated in the hannels, where the darters were usually abundant and ore easily obtained. Collections were made by minow seine at approximately 2-week intervals from ugust to November in 1967 and at irregular intervals roughout 1968 and early 1969 in an effort to obtain much information as possible for all seasons. Conderable difficulty was encountered in obtaining specimens during several periods of high water, but ventually specimens were secured for every month xcept January. Specimens collected during the 2-year udy period were distributed as follows: February, 12; arch, 8; April, 6; May, 27; June, 26; July, 20; August, 3; September, 60; October, 53; November, 38; and ecember, 2, for a total of 300 specimens.

Supplemental collections from previous years in the me area provided additional specimens and helped l gaps resulting from flood periods. A total of 526 eserved specimens were examined during the study for formation on food and reproduction within the study ea, but the information on growth and other facets the life history were based on the 300 specimens cured during the study period.

Specimens from the study area were measured, their e and sex were determined, and details of color ttern and the presence of external parasites were noted. Young darters were examined for developmental features and for growth. Most of the adults were dissected and gonad conditions were noted. As spawning time approached, the dimensions of gonads were recorded and ovarian egg counts were made on several females. Age determinations were made by counting the number of annuli on scales removed from the dorsum on the left side of the body near the junction of the spinous and soft dorsal fins.

The stomachs of most of the adults and 20 percent of the young were examined for food organisms. Stomachs of some potential predators of *P. sciera* were also examined for darter remains.

During the spring, water and air temperatures were routinely taken, and notes were made on the river and weather conditions, coloration of the fish, and habitats in which specimens were captured. Care was taken not to deplete the darter population, and no more than 35 specimens were taken, even when the species was abundant and easily captured. Specimens were dropped into approximately 10-percent formalin as soon as they were captured.

Living specimens were brought to the laboratory from time to time so that their behavior could be observed in aquaria. When it became evident that captives were not going to spawn in the laboratory, eggs and sperm were stripped from ripe adults into petri dishes and kept until the eggs hatched.

On October 17, 1967, a quantitative sample was taken one-half mile north of Greenup with an electric seine to estimate the composition of the total fish fauna at the site, the numerical relationships of the component species, and the number of individuals per square yard of habitat. A 150-foot stretch of the river was blocked off by minnow seines held in place by steel rods, so that fishes could neither enter nor leave the enclosed area, and the number of square yards was calculated. A 30-foot electric seine with 15-inch drop cords at 30-inch intervals was moved from the downstream to the upstream block repeatedly in an attempt to kill all fishes in the enclosure. Dead fishes were picked up by hand and with dipnets in clear water; those in deep or turbid pools where they could not be seen were removed by repeated seining of these pools.

HABITAT AND ASSOCIATED SPECIES

In the study area all sizes of *P. sciera* were most often found in that portion of the river channel that had a combination of gravel bottom, rapid or fairly rapid current, and a depth of at least 1 foot. The species was seldom found over bottom materials other than gravel and never found in quiet pools or shallow water. Accumulations of branches and leaves in the gravel of the channel often contained darters, suggesting that these were hiding or resting sites. Captive darters hid under large rocks or other objects on the bottom of the aquarium.

In Ohio a preference on the part of dusky darters

for rooted plants was noted by Trautman (1957:536); however, no rooted plants were present in our study area, and the species was abundant. Elsewhere in its range, this darter is reportedly common in habitats free of aquatic vascular plants (Blair 1959:10; Gerking 1945:85; Suttkus & Ramsey 1967:140).

Lotic habitats in moderate-sized creeks to large rivers are occupied by *P. sciera.* In the study area streams only 6–8 feet wide contained the species at least in the summer months. Records are also available for such large streams as the Wabash, Ohio, and Mississippi rivers.

An opportunity to quantify the relative abundance of associated species was available with the use of the electric seine in the section of river blocked off with seines, and it provided a concept of the ecological community of which the dusky darter was a component. Within the enclosed 507 square yards of water averaging 1 foot in depth, 750 fishes of 18 species were collected. The minnows *Pimephales vigilax, Notropis whipplei,* and *Notropis spilopterus* were clearly the most abundant associated species (Fig. 3), their combined totals comprising 78 percent of the total number of fish present. Other frequent associates were the minnows *Phenacobius mirabilis, Ericymba buccata,* and *Campostoma anomalum,* and the hog sucker *Hypentelium nigricans.*

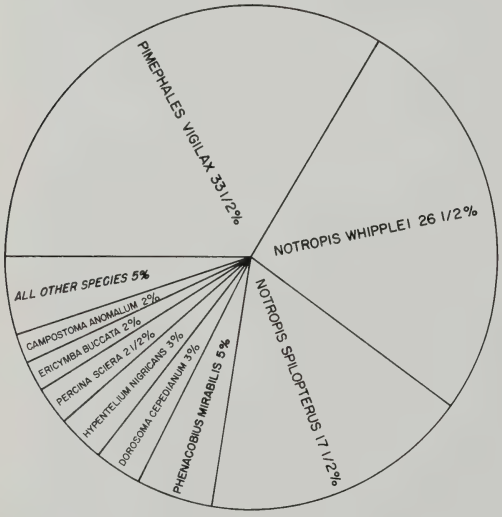

Fig. 3. — Relative abundance of fish species associated with *Percina sciera* as determined by a quantitative sample from the Embarras River near the study area.

Percina sciera ranked seventh in abundance (2.5 percent of the total number of fish) and was more than five times as abundant as the second most abundant darter, *Percina phoxocephala.* Other darters found in the study area were *Etheostoma blennioides, E. caeruleum, E. nigrum, Ammocrypta pellucida, Etheostoma spectabile, Percina maculata, P. caprodes, Etheostoma asprigene, E. chlorosomum, E. gracile, E. flabellare,* and *E. histrio.*

REPRODUCTION

Reproductive Cycle of the Male

Most males were sexually mature and ready to spawn the first spring following their hatching. Of seven males approximately 1 year old collected May 27, 1969, one 48 mm in standard length had undeveloped testes and no indication of breeding coloration, but six others more than 55 mm in standard length were more darkly pigmented and appeared ready to spawn at that time. However, yearling males were smaller and had less intense breeding colors than older males and were probably at a disadvantage in attracting females.

As the breeding season approached, an over-all duskiness masked the normal olive-green ground color, and the row of lateral blotches became obliterated by blackish vertical bands which were narrowly but distinctly separated from each other. The top of the head, belly, breast and fins also darkened, and a dark blotch developed on the posterior portion of the spinous dorsal fin. A faint, pale orange band appeared on the distal part of the spinous dorsal fin.

Each scale on the dorsal half of the body could be seen, with magnification, to be sprinkled with several brilliant blue-green iridocytes that gave the fish an iridescence. Melanophores concentrated on the subdistal portion of each pelvic fin and the soft dorsal fin to form a discrete, thin, pigmented band margined distally by a transparent band (Fig. 4).

In our study period, the earliest specimen that showed pronounced breeding coloration was a 2-year-old male collected on April 28. He was darkly pigmented over the entire body and had developed the dark vertical bands and dark blotch at the posterior base of the spinous dorsal fin. The height of breeding coloration was reached in late May, when large males lost the vertical bands and became almost uniformly black.

Breeding males did not develop tubercles, and according to Collette (1965:577) none of the species of the subgenus *Hadropterus* has breeding tubercles.

The development of the testes consisted of a gradual increase in size until spawning and then underwent a sharp decrease. In a September-collected male, the length of one testis was 10 percent of the standard length; in a March specimen, 13 percent; in May and June specimens, 14 percent; but in a July specimen, only 8 percent.

Reproductive Cycle of the Female

Like males, females usually were sexually mature at 1 year of age but, unlike males, they were ready to spawn at a smaller size (approximately 40 mm in standard length). Yearling females collected in May

Fig. 4.—Pigmentation patterns of breeding male and female *Percina sciera*.

nd June less than 40 mm lacked mature eggs, but rger yearlings collected at the same time and place ntained mature eggs and appeared ready to spawn.

The reproductive cycle of the female was divisible to a prespawning period, the spawning act, and postawning period. The prespawning period was characrized by the differentiation and maturation of ova, e spawning act by the release of mature eggs, and the ostspawning period by absorption of the remaining va and recovery of the ovaries.

Two characteristics of ova maturation — size and olor — were easily observable and allowed the develping ova to be categorized. The ova were all small in e earliest stages of maturation, but in late spring hen development was most rapid the ova were constently present in three different size groups: less than mm, between .6 and 1.0 mm, and from 1.1 to 1.5 m in diameter. The smallest ova were white, the interediate ones were yellow, and the largest were dark llow or orange.

Percentages of differentiated ova (Table 1) were sed on estimates rather than actual counts but the timates were consistently made and are comparable. he prespawning period began when the ova first gan to differentiate in early October. A specimen llected in September had almost no ova that could be assed as differentiated, but one collected on October had an estimated 10 percent of the ova differentiated, hough they were still white and less than .5 mm in ameter. The initiation and progression of ova develoment may vary with the size and age of the fish and ssibly with climatic conditions.

Early stages of differentiation proceeded slowly, and not until the water warmed and spawning time approached did recognizably mature eggs appear (Fig. 5). Examination of a specimen collected on March 7 indicated that as many as 90 percent of the ova had differentiated but all were white and less than .5 mm, just as those of the October specimen had been.

A specimen collected on April 28 contained ova clearly divisible into the three size and color categories mentioned above (the smallest ova were white and less than .5 mm in diameter, the intermediate ova yellow and between .6 and 1.0 mm, and the largest orange and between 1.1 and 1.5 mm). Sixty-four per-

TABLE 1.—Differentiation and growth of ova in *Percina sciera* collected in the study area between August 4, 1967, and June 8, 1969.

Date of Collection	Estimated Percent of Differentiated Ova	Percent of Differentiated Ova by Size Group		
		.1–.5 mm	.6–1.0 mm	1.1–1.5 mm
Oct. 14	10	100	0	0
Nov. 1	15	100	0	0
Dec. 7	25	100	0	0
Feb. 23	80	92	8	0
Mar. 29	75	69	31	0
April 28	over 90	64	25	11
May 15	over 90	64	24	12
June 25[a]	over 90	60	26	14
July 7[a]	over 90	56	24	20
Aug. 4	10	100	0	0
Sept. 21	0	0	0	0

[a] 1968 only; in 1969 *Percina sciera* spawned in early June.

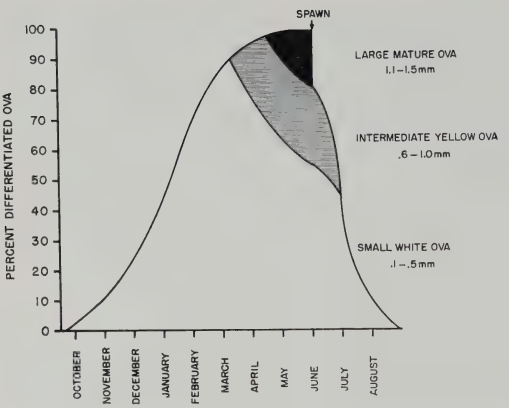

Fig. 5.—Differentiation of ova during the year, as inferred from data in Table 1.

cent were in the small-ova category, 25 percent intermediate, and 11 percent in the large-ova group.

The general pattern of differentiation during the spring months was a decrease in the percentage of small ova and an increase in the percentage of large ova (Table 1). The number of intermediate ova after April remained approximately the same (Fig. 5). Essentially the same pattern was found in *Etheostoma gracile* by Braasch & Smith (1967:6), but they also found a general increase in the relative proportion of intermediate ova present.

The ovaries of the dusky darter gradually increased in size during the prespawning period (17 percent of the standard length of a September specimen, 21 percent in a March specimen, 27 percent in an April specimen, 35 percent in a May specimen, and 34 percent in a June specimen) as the eggs developed. The gradual enlargement of the ovaries coincided with enlargement of the testes in the male; both showed most pronounced increases in April and reached their greatest sizes in May and June. The ovaries of postspawning females were greatly reduced in size.

Between 500 and 2,000 ova were produced by one female in one season, but only about 10 percent reached mature size. The number of mature eggs in specimens examined ranged from 80 to 196. Although an actual count of eggs laid by a dusky darter could not be made, other studies on darters indicate that they normally lay the total complement of mature eggs (Fahy 1954:166; Winn 1958*a*:181). A relationship exists between the size of the female and the number of eggs produced, the larger females producing more eggs.

Mature ova tended to be concentrated near the center of the ovary and, in preserved specimens, were easily detached from the surrounding tissue.

Following the act of spawning, unlaid eggs atrophied and were ultimately absorbed. The ovaries gradually shrank and lost the yellow-orange color. A quiescent or recovery stage followed the absorption of the egg materials, during which time no egg development was detectable.

As spawning time approached, the genital papilla enlarged, becoming tubular, and the breeding colors intensified. The breeding female became more intensely colored; the yellow color of the dorsum became brighter, the undersides remained white, and the lateral blotches appeared more intense. While the melanophores of the breeding male were jet black and interspersed with numerous blue-green iridocytes, melanophores of the breeding female were brown in color and iridocytes were sparse. The striking yellow of the dorsum resulted from concentrations of yellow pigment along the posterior edge of each scale.

Spawning

The dates of spawning and duration of the spawning period appeared to vary from year to year, probably as a result of climatic and river conditions. In 1967, juveniles collected on August 4 averaged 30 mm in standard length, and to have attained such a size the eggs were probably laid sometime in July.

In 1968, darters could not be obtained in June because of high water, but on July 7 six adult females were captured. One appeared to be in an immediate postspawning condition and five contained large numbers of mature ova, indicating that they had not yet spawned. It is probable that the peak of the 1968 spawning was in early July. However, a 26-mm young collected on July 7 was the result of a spawning perhaps as much as a month earlier.

In 1969, peak spawning occurred between May 27 and June 8. Females collected on the first date were filled with mature ova; most of those collected on June 8 had spawned and were without mature ova. On both dates both males and females were very abundant in the shallower portions (1–3 feet deep) of the gravel raceway, the apparent spawning habitat.

The Embarras River was subject to several floods during the study period, and the unusually deep channels, inundated floodplains, and turbid water could have hindered spawning. The comparatively late spawning in 1968 (and perhaps also in 1967) is assumed to have been late because of the June floods. It appears that spawning in June is the preferred time for the species at this latitude.

Reproductive behavior is varied in darters, and the relative complexity is believed to be correlated with the extent of specialization. Little information is available on the mating behavior of *Percina,* the principal published studies being those for *P. peltata* (New 1966; Loos & Woolcott 1969), *P. notogramma* (Loos & Woolcott 1969), *P. caprodes* (Winn 1958*a*, 1958*b*: 192–194), *P. maculata* (Petravicz 1938; Winn 1958*a*, 1958*b*:194), and *P. copelandi* (Winn 1953, 1958*a*, 1958*b*:202).

Although actual spawning was not observed, some

inferences can be drawn from observations on aquarium-held fish and from the morphology of *P. sciera* and its relationships to species in which the spawning behavior is known. Aquarium-held males during late May and early June underwent an array of color changes in response to particular stimuli, including the proximity of females. The only sexual behavior on the part of males, other than metachrosis, was an observation of tail-beating by a male sitting directly in front of a large female. A pair of newly captured darters was placed in an aquarium on May 28, 1969, and within a few hours the female appeared ready to spawn, repeatedly swimming over the male and alighting in front of him. The male did not respond, and 24 hours later the female had apparently lost interest.

The presence of increased sexual dimorphism (larger size and darker color of male) in the spring suggests that sex recognition in the species is good. The generalized condition of a midventral row of specialized scales suggests that the male mounts the female and aligns his body with hers during fertilization and deposition of the eggs in a manner similar to that of *P. peltata* and *P. notogramma*. It is likely that spawning in *P. sciera* is no more elaborate than a free scattering of eggs over the gravel substrate, fertilization, and with that, the spawning act is completed.

DEVELOPMENT AND GROWTH

Development

Observations of the development of egg, embryo, and larval forms of *P. sciera* were made from June 8, 1969, when eggs and sperm were successfully stripped from a pair of adult fishes, to June 19, when the fry died.

The eggs were transparent, spherical, and adhesive. They averaged 1.5 mm in diameter and had a yellowish oil droplet .6 mm in diameter. At 36 hours the typical embryo, developing at 74–78°F, was 3.0 mm long. Midbrain and forebrain regions, optic vesicles, otic vesicles, and somites in the trunk region were clearly defined. The heart was beating and body contractions were frequent. No melanophores were visible.

At 60 hours, the dusky darter embryo was 4.8 mm long. The eye was heavily pigmented (black). A fin fold extended from the yolk sac ventrally to approximately one-half of the length of the embryo dorsally. The number of somites ranged from 26 to 29. Melanophores were scattered over the lower portion of the yolk sac. Unpigmented cells were visibly moving through the vitelline veins and dorsal aorta. The embryo was quite active and had a heart rate of 140 beats per minute.

At 65 hours, the blood was noticeably pink, and melanophores were present along the ventral side of the tail. At 84 hours, the eyes were metallic brown in color, and fin buds had formed.

At 74–78°F the darters began hatching at 90 hours and had all hatched by 108 hours. Hatchlings (Fig. 6) averaged 5.5 mm in total length. They had red blood, numerous melanophores on the ventral half of the body, and metallic gold eyes. In 2-day-old larvae the lower jaw was evident, rays had formed in the pectoral fins, and the yolk sac was small. At 3 days obvious breathing actions could be observed and at four days the fry were feeding on prepared food. At 5 days the yolk sac was gone and numerous melanophores were distributed along the myomeres. The fry died on the 6th day.

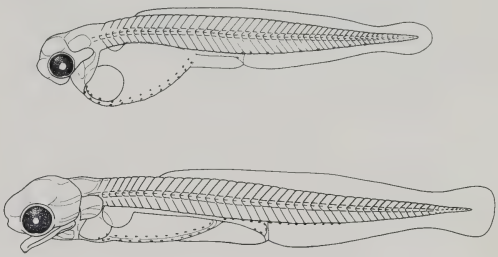

Fig. 6. — Development of morphological features of *Percina sciera* as illustrated by a hatchling and a 2-day-old larva.

The smallest specimen taken from the study area, a 16-mm (standard length) male (Fig. 7) collected on August 4, 1967, and estimated to be about 3 weeks old, had body proportions essentially those of adult fish but with characteristics reminiscent of the larval form. The head and eyes were large, and the fins were small in proportion to those of the adult. Squamation was incomplete but well advanced, the scales having formed over the body except for the area to either side of the anterior dorsal fin, the nape, and the anterior portion of the belly. Pigmentation was poorly developed, but the lateral blotches, the band around the snout, and spots of color in the fins were beginning to form. A short segment of the lateral line had formed in the region above the operculum but was absent on

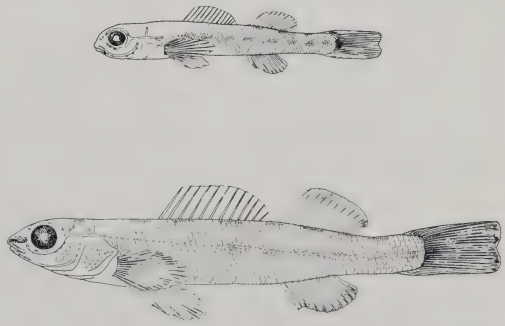

Fig. 7. — Juveniles 3 weeks (16 mm) and 5 weeks (26 mm) of age.

the rest of the body. The sensory canals on the head were present but incompletely pored, and the supratemporal canal was widely interrupted medially. The opercular spine was small and weak. The midventral specialized scales were not present.

In a 26-mm male (Fig. 7) collected at the same time and place as the 16-mm fish, the body proportions were more nearly those of the adult, except that the eyes were still relatively large and the fins proportionally small. Squamation was complete except on the nape. The pattern of pigmentation was that of adult fish, although less intense. The lateral line was complete. The head canals were complete and apparently fully pored, and the specialized scales were present on the midventer. In individuals 31- to 35-mm long, scales were present on the nape.

The basic color pattern of the adult was formed quite early, but pigmentation remained subdued throughout the first year. It intensified continuously thereafter, older fishes always being darker than younger ones in any given sample.

Growth

Standard length frequencies of specimens taken from the study area from August 4, 1967, to July 1, 1969, indicated rather rapid growth in the species, notably during the first few months of life. Presumably growth continues throughout life, but the rate diminishes with age.

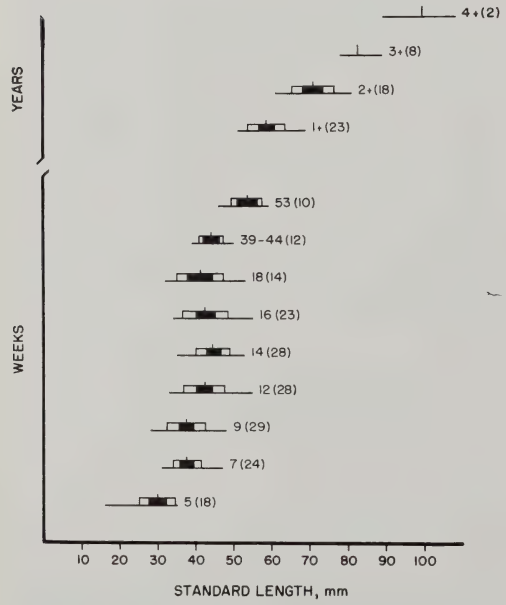

Fig. 8.—Growth of *Percina sciera* in millimeters standard length. The vertical line represents mean; horizontal line, range; hollow rectangle, one standard deviation to either side of mean; solid rectangle, two standard errors to either side of mean. Numbers in parentheses are specimens measured. Young in the first sample were estimated to be 5 weeks old; other samples were aged from the collection date of the first sample.

The growth data for samples taken from August, 1967, to July, 1968, (Fig. 8) showed a continuous average increase in size, except during late October (16 weeks) and November (18 weeks), when the mean standard lengths of two collections averaged less than those of the early October (14 weeks) collections. This reversal, which also occurred in samples from November, 1968, is assumed to be the result of an emigration of the larger fish from the comparatively shallow raceway being sampled to the deeper channel as winter approached.

In all but one sample of young taken in the study area, males averaged larger than females. The average standard length of darters between 1 and 2 years old was 57.5 mm for females and 61.4 mm for males; of those between 2 and 3 years old it was 62.3 mm for females and 73.3 mm for males. The largest specimen examined was a 4½-year-old male 108 mm in standard length collected November 1, 1968, in the Little Wabash River.

A transition from a predominantly pelagic to benthic swimming behavior was noted between young and adult dusky darters in aquaria. Young fish were active and spent most of their time swimming about and rarely resting on the bottom. Older fish, however, were usually quiet, occasionally darting about over the bottom or actively swimming.

PHYLOGENETIC RELATIONSHIPS

Within the subgenus *Hadropterus, P. sciera* and *aurolineata* are most alike in morphological features and least often found together where the ranges of all four members of the subgenus overlap. *P. nigrofasciata* appears to be more closely related to *P. sciera* and *P. aurolineata* than to *P. lenticula* (Suttkus & Ramsey 1967:138).

Among subgenera of *Percina, Hadropterus* appears to be intermediate between the more primitive *(Hypohomus, Swainia, Percina)* and the more advanced *(Cottogaster, Ericosma, Imostoma, Alvordius)* forms but probably is more closely related to the primitive subgenera. Primitive characteristics exhibited by *Hadropterus* include highly pelagic habits, large size, high meristic counts, and the modest specialization of the midventer row of scales in the males.

One of the anatomical features considered to be an indicator of phylogenetic position of darters is the degree of abatement of the gas bladder (Winn 1958a: 188). In *Etheostoma,* bottom-dwelling habits are accompanied by a reduction or loss of the bladder. In some species of *Percina* the gas bladder is present but small and in various stages of reduction. However, it is relatively large in *P. sciera,* indicating little phyletic

advancement. In three specimens examined, the gas bladder averaged about 16 percent of the standard length of the fish. In a 2-year-old male, 69 mm in standard length, it was 10 mm long, 3 mm wide, and 2 mm deep.

POPULATION CHARACTERISTICS

Density

Some information on population density of *P. sciera* in the middle Embarras River was provided by the electric-seine sample described earlier. The approximately 507 square yards of river (average depth 1 foot) yielded 750 fishes of various kinds for an average of 1.48 fish per square yard and one dusky darter for 25.3 square yards. However, rather than being uniformly distributed in the 507 square yards, the darters tended to occupy their optimal habitat, a gravelly raceway that comprised about one-fourth (127 square yards) of the area sampled. Thus a more realistic figure would be one dusky darter per 6.3 square yards of habitat.

Composition

Of the 20 dusky darters secured by shocking in the barricaded area, 17 (85 percent) were young-of-the-year and 3 (15 percent) were 1-year-old fish. The proportion of young to older individuals is remarkably similar to the age analysis made for all specimens examined during the 1967–1969 study period: 82.8 percent young-of-the-year, 13.7 percent yearlings, 2.7 percent second-year fish, and .7 percent third-year fish.

Approximately equal numbers of males (117) and females (124) were produced (Table 2), and the overall sex ratio of young can be assumed to be 1:1; however, males appeared to have somewhat greater longevity than females. Of 35 fish examined that were 2 or more years in age (including several not from the study area), 28 (80 percent) were males and 7 (20 percent) were females. However, females live to an age of at least 3 years, a fact substantiated by the presence in the Illinois Natural History Survey collection of a large female slightly more than 3 years old from Scott Co., Missouri. The oldest specimen examined was the previously mentioned 108-mm (standard length) male from the Little Wabash River of Illinois (4½ years).

TABLE 2.—Distribution of sexes and year classes in samples of *Percina sciera* taken from the study area between August 4, 1967, and June 8, 1969.

Sex	Number by Year Class				
	—1	1+	2+	3+	*Total*
Males	117	8	5	2	*132*
Females	124	32	3	0	*159*
Total	*241*	*40*	*8*	*2*	*291*

Although no evidence of predation on *P. sciera* was found, the primary control of population levels must be a combination of predation, the inherent limited longevity of the species, and the harshness of the physical habitat, particularly the fluctuations in the level of the river.

Migration

Although the dusky darter was the most common darter in the study area and consistently easy to collect during summer and fall, at times specimens could not be obtained. Sometimes they could not be collected because excessively high water prevented effective seining, but at other times (November of 1967, December of 1968) they could not be obtained even though the water levels were low and habitats in which the dusky darter had previously been plentiful were seined repeatedly.

Between October 3, 1967, when the species was very abundant (31 captured in 20 minutes) to November 4, 1967, when only 3 darters could be captured in 2 hours of seining, the population in the river channels had become greatly reduced. October 3 was clear, warm, and typically autumnal. By November 4, cold weather had begun and the air temperature was only 33°F. During this interval an emigration from the river channels to another habitat had occurred. By March, individuals of all sizes were again present in the channels.

Several species of darters are known to immigrate into tributaries in the spring, either to spawn and then immediately return to the habitat previously occupied or to remain throughout the summer and return to the river in the autumn (Lake 1936:817; Winn 1958*a*:163–164). Three tributaries of the Embarras River are located within 4 miles of the study area, and 18 collections have been made in them over the last 10 years. Three of 11 made in the summer months contained specimens of *P. sciera,* but none of the 7 collections made at other seasons contained specimens even when extensive effort was made and all types of habitats vigorously sampled in over a mile of the tributary, as was done November 25, 1967. Specimens had been collected in the same area in June of 1967, and several were collected the following day (November 26, 1967) in the Embarras River proper.

A winter movement out of the river channels and spring immigrations into them, followed by fall emigrations from tributaries, were the only migratory aspects observed in this study.

Territoriality

The presence of pronounced sexual dimorphism (larger size and darker color of the male) suggests that the male establishes and defends a territory. Aquaria used to hold dusky darters were evidently too small to allow the establishment of territories, and defended

areas were not well defined. However, certain males did select stations at which they remained, except to feed, and they were perpetually antagonistic toward any other males that approached their stations. No aggressiveness by males toward females or between females was noted.

DIET AND FEEDING HABITS

In 108 specimens of *P. sciera* examined for stomach contents, only current-dwelling insect immatures were found. The number of individual food items was often quite high, with as many as 116 and an average of 12.5 items per fish, but the variety of organisms was consistently low. During the entire study only midge larvae and pupae; larvae of caddisflies, black flies, and snipe flies; and naiads of mayflies and stoneflies were encountered in the stomach contents (Table 3). The principal food items were midge and black fly larvae, although some seasonal variation in the diet occurred (Fig. 9). Caddisfly larvae formed a large portion of the diet during the summer, and the dipterans and mayflies were the main components during other seasons. The variation was probably correlated with the relative availability of the different insect larvae throughout the year.

TABLE 3.—Stomach contents of *Percina sciera* of all ages collected from the Embarras River between August 4, 1967 and June 8, 1969. Figures in parentheses are numbers of stomachs examined.

	Percent Occurrence of Food Organisms in Stomachs Examined										
Food Organism	Feb. (10)	Mar. (8)	Apr. (6)	May (10)	June (10)	July (6)	Aug. (13)	Sept. (16)	Oct. (16)	Nov. (11)	Dec. (2)
Midge larvae, pupae	10.0	100.0	83.3	20.0	40.0	50.0			87.5	27.3	....
Black fly larvae	70.0	37.5	83.3	80.0	50.0	33.3	61.5[a]	87.5[a]	12.5	9.1	....
Caddisfly larvae	10.0	....	....	10.0	20.0	83.3	15.4	25.0	37.5	9.1	....
Mayfly naiads	10.0	....	33.3	40.0	70.0	66.7	15.4	75.0	50.0	18.2	....
Snipe fly larvae	....	....	....	....	....	16.7	....	....	6.3	....	....
Stonefly naiads	....	12.5	....	....	....	....	....	....	....	....	....

	Mean Number of Food Organisms Per Stomach										
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Midge larvae, pupae	0.4	8.9	2.5	1.0	1.4	2.2			7.9	1.5	....
Black fly larvae	1.4	1.4	10.3	29.6	4.0	0.3	11.8[a]	10.3[a]	1.3	0.2	....
Caddisfly larvae	0.1	....	....	0.1	0.3	16.2	0.2	2.2	1.4	0.2	....
Mayfly naiads	0.1	....	0.3	1.9	2.5	1.8	0.8	4.9	1.3	0.2	....
Snipe fly larvae	....	....	....	....	....	0.2	....	....	0.1	....	....
Stonefly naiads	....	0.1	....	....	....	....	....	....	....	....	....

[a] Midge and Black fly larvae not separated in August and September.

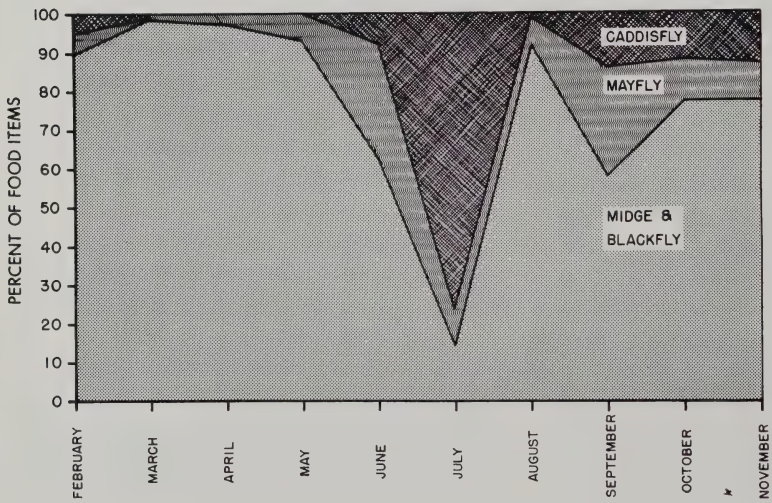

Fig. 9. — Seasonal variation in the diet of *Percina sciera* of all sizes. Percent of food item refers to total contribution in all fish examined each month.

Heaviest feeding occurred during May, just before the spawning period. Although feeding was reduced in winter as Fahy (1954:152) found in adult *Etheostoma blennioides,* some food ingestion probably occurs throughout the year. The deposits of fat around the intestine were approximately the same all year, except for the prespawning period during which time the gonads were developing and the amount of stored adipose tissue diminished. After spawning, the fat reserve was gradually replenished.

As the darters increased in size, there was a change in the over-all diet composition (Fig. 10). In fish less than 65 mm standard length, midge larvae were the predominant food item; caddisflies were seldom eaten. However, in fish 65–80 mm, the diet consisted primarily of caddisfly larvae. The average length of all darters containing caddisfly larvae was 63.5 mm, and for those containing dipteran larvae it was 50.1 mm. The proportion of mayflies and other miscellaneous food items was about the same in both small and large darters.

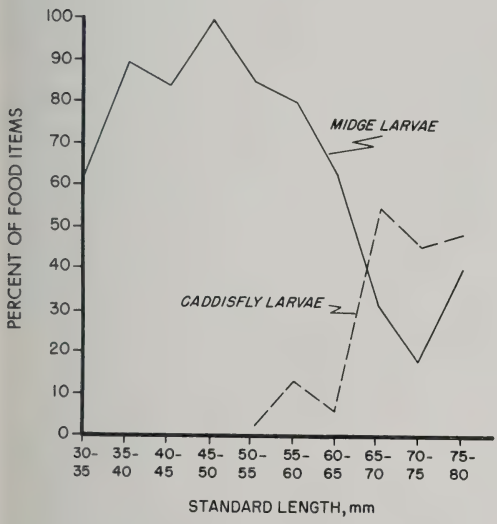

Fig. 10. — Change in relative consumption of midge larvae and caddisfly larvae as *Percina sciera* increases in size.

No data are available for the food of recently hatched young. In this study the smallest young contained dipteran larvae like those found in larger fish. However, the newly hatched darter, because of its small size, must feed for a time on plankton and other microorganisms, as the hatchlings of other darters are known to do (Braasch & Smith 1967:11). The main criteria determining differences between the diets of young and adult fish (Fig. 11) appear to be the size and availability of the prey item.

Aquarium-held specimens of *P. sciera* readily fed on mosquito wrigglers, phantom midge larvae, and sections of small earthworms.

INTERACTIONS WITH OTHER ORGANISMS

Competition

Limited information is available on the feeding habits of several of the fish species living in the study area. However, only those maintaining sizeable populations in the same habitat as the dusky darter needed to be considered as important competitors for food. The most likely of these was the slenderhead darter, *Percina phoxocephala,* which was rather abundant in much the same habitat and had a diet somewhat similar to that of the dusky darter. Slenderhead darters were noted to

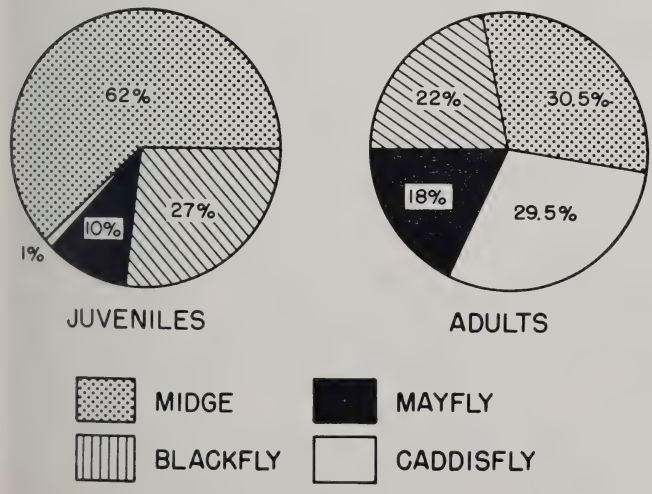

Fig. 11.—Composition of the diets of juvenile and adult *Percina sciera* collected in the study area from August 4, 1967, to July 7, 1968.

feed on mayfly larvae and pupae, dragonfly larvae, *Chironomus* larvae, and water bugs (*Corixa* sp.) (Forbes & Richardson 1920:286). Our examination of stomachs of *P. phoxocephala* in the Embarras River revealed a diet similar to that of *P. sciera,* but it included a greater variety of items. Some competition between the two species was suggested, but whether or not the food supply ever became low enough to cause population-limiting competition (demand in excess of supply) could not be ascertained. Collections of *P. sciera* examined throughout the year contained at least some specimens with full stomachs and thus competition for food was probably not a limiting factor for populations of *P. sciera.*

Competition for habitat space between *P. sciera* and most other darters occurring in the study area was also probably minimal because of differences in preferred microhabitat. For example, *Etheostoma blennioides* and *E. caeruleum* selected shallower, faster, and more rocky riffles. *E. nigrum* and *Percina maculata* preferred pools or slow-flowing raceways with sandy or silty bottoms. *Etheostoma spectabile,* which prefers headwaters and small tributaries, was uncommon in the river. *Ammocrypta pellucida* was rigidly restricted to sand-bottom areas. *Percina caprodes* and *Etheostoma histrio,* somewhat similar to one another in their habitat requirements in the Embarras River, selected fairly deep, rapid-flowing water with brush or debris on the bottom. Other species of darters were present in the study area only in extremely small populations.

However, *P. sciera* and *P. phoxocephala* appeared to be somewhat competitive for habitat and possibly breeding space inasmuch as they were the two most abundant darters in the study area and frequently were found together. *P. phoxocephala* is more plastic in its microhabitat choices, sometimes occupying swift water over sand, silty-sand bottom, or shallow riffles.

Competition for breeding sites was not likely among darters in the study area, inasmuch as, so far as breeding habits are known, all species except *P. phoxocephala* bred earlier than *P. sciera.*

Predation

No evidence of predation on dusky darters was found. By far the most abundant, large predaceous fish in the study area was the spotted bass, *Micropterus punctulatus.* Concurrent with the life-history study of the dusky darter, an investigation of the feeding habits of the spotted bass was conducted. The stomachs and intestines of 114 bass of various sizes were examined, and the only predation on darters noted was the remains of three specimens of *Etheostoma nigrum* (Smith & Page 1969).

Parasitism

A high incidence of leech parasitism was noted on dusky darters from June to November in the study area. A total of 109 leeches was removed from 249 darters examined for ectoparasites, most often from the proximal portion of the caudal fin. The leeches, identified as *Piscicolaria reducta* Meyer by Dr. M. C. Meyer, were more numerous on large darters, some having as many as four leeches. The number of leech parasites per fish on young darters examined was .39 (215 fish), on yearlings .57 (31 fish), and 2-year-olds 2 (3 fish). No other external parasites were noted.

Hybridization

Hybridization involving the dusky darter has been recorded in nature and as a result of experimental laboratory crosses. Hybrids between the dusky darter and blackbanded darter *(Percina nigrofasciata)* were reported by Suttkus & Ramsey (1967:141) from the Pearl River in Louisiana, and between the dusky darter and logperch *(Percina caprodes)* by Hubbs & Laritz (1961*a*) from the San Gabriel River in Texas. Also, an intergeneric hybrid between the dusky darter and orangethroat darter *(Etheostoma spectabile)* was reported by Hubbs & Laritz (1961*b*) from the San Marcos River in Texas.

Clark Hubbs and his students at the University of Texas have made artificial intergeneric and interspecific crosses involving the dusky darter and several other species of *Percina* and *Etheostoma* (Hubbs 1959; Hubbs & Strawn 1957).

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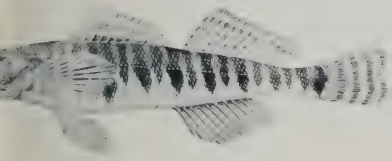
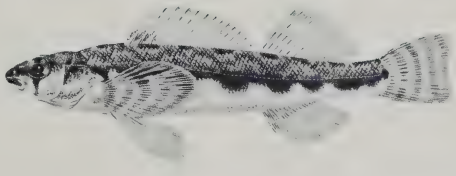
N ECOLOGICAL STUDY OF FOUR DARTERS F THE GENUS *PERCINA* (PERCIDAE) THE KASKASKIA RIVER, ILLINOIS

David L. Thomas



P. caprodes

P. maculata



P. phoxocephala

P. shumardi

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Fig. 1. — Map of the drainage basin of the Kaskaskia River in Illinois. Collecting stations are numbered consecutively from the headwaters to the mouth.

COVER ILLUSTRATION: Adults of four species of darters. From watercolors by Mrs. Alice Ann Prickett

AN ECOLOGICAL STUDY OF FOUR DARTERS OF THE GENUS *PERCINA* (PERCIDAE) IN THE KASKASKIA RIVER, ILLINOIS

By David L. Thomas

REPRODUCTION OF DARTERS of the genus *ercina* has been studied and reported on by Reighard 1913), Petravicz (1938), Winn (1953, 1958*a*, 1958*b*), ew (1966), Page & Smith (1970), and others. These nd other studies, such as those of Karr (1963), were stricted to small geographic areas and do not demonrate geographic variation in aspects of the life history.

The logperch, *P. caprodes* (Rafinesque)[1]; blackside arter, *P. maculata* (Girard); slenderhead darter, *P. hoxocephala* (Nelson); and the river darter, *P. shuardi* (Girard) were studied in the Kaskaskia River uring the period from June 1965 to January 1967. This ver arises 4 miles northwest of Champaign-Urbana in hampaign County, Illinois, flows in a southwesterly rection for about 350 miles, and empties into the Misppi River approximately 7 miles above Chester (Fig. . In its upper basin the Kaskaskia River flows over isconsin till. For a number of miles below the Shelbylle Moraine, sand outwash predominates, but below andalia the river bottom is mainly Illinoian drift of nd, silts, and loams over a subsoil of compact clay. Fig. 2 shows the types of bottom materials along the river.

The descent of the river is gradual (Fig. 3), with a total fall of about 450 feet between source and mouth. The most rapid descent is through Moultrie County, where the river drops 3 feet per mile (University of Illinois 1937).

Information on the distribution and abundance of the four darters was collected from 12 stations (Fig. 1 and Table 1). Because of their distinctiveness, four main areas were selected for further study: New Athens-Evansville (Stations 10 and 11), Carlyle (8, 9), Vandalia (6, 7), and Sullivan (3).

Much of the research was aimed at determining the relationships between the populations of these darters and the changing physical and biotic factors of the river. Information was gathered on habitat preference, population structure, growth, and food habits, which allowed

[1] The population of logperch in the Kaskaskia River consists of *P. rodes carbonaria* x *caprodes* intergrades.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12, and is a contribution from the Section of Aquatic Biology of the Illinois Natural History Survey. It was submitted in its original form by David L. Thomas in partial fulfillment of the requirements for the degree of Master of Science in the Graduate College of the University of Illinois. Mr. Thomas, a former technical assistant at the Illinois Natural History Survey, is presently a research biologist for Ichthyological Associates, Middletown, Delaware.

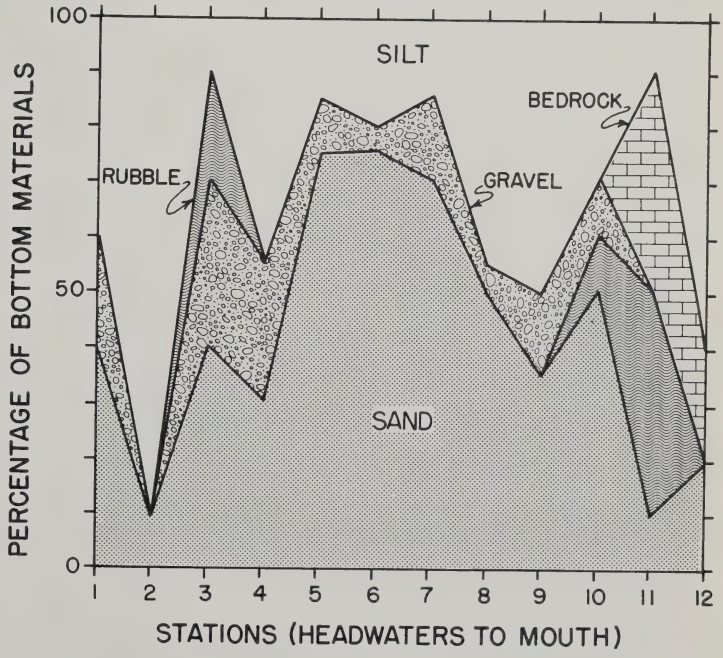

Fig. 2. — Percent of bottom materials each station in 1965 and 1966.

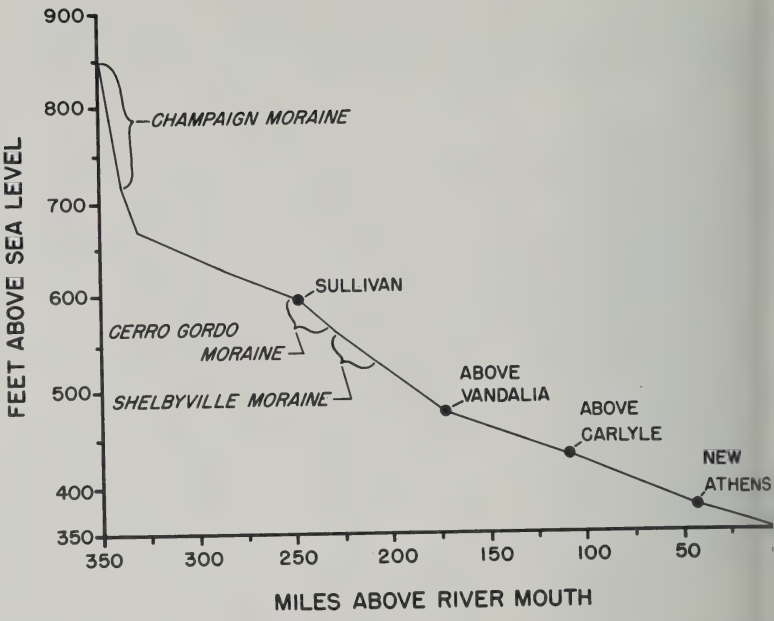

Fig. 3. — Gradient profile of the Kaskaskia River with locations of four main collecting stations (modified from Luce 1933, p. 73).

TABLE 1. — Description of stations where the four *Percina* darter species were collected. Dates indicate when measurements were made. Where two years are shown, average values were used.

	Station Number and Location	Length, Feet	Average Width, Feet	Average Depth, Feet	Acres	Distance from River Mouth, Miles
1	Headwaters (1966)	182	39	0.8	0.16	..
2	Arcola (1965-66)	197	43	1.6	0.20	286
3	Sullivan-Bruce (1965-66)	259	48	1.8	0.29	250
4	Eagle Creek (1965-66)	238	60	2.5	0.33	232
5	Moore's Bridge (1965-66)	342	62	1.7	0.50	209
6	Above Vandalia (1965-66)	453	73	2.6	0.78	172
7	Below Vandalia (1966)	218	60	2.3	0.30	136
8	Above Carlyle (1965)	450	84	4.9	0.86	108
9	Below Carlyle (1965-66)	380	85	3.6	0.74	105
10	Below New Athens (1966)	527	106	3.1	1.28	47
11	Above Evansville (1966)	300	120	2.1	0.68	13
12	Below Evansville (1966)	300	125	3.8	0.86	6

comparisons to be made of certain life history featu over 350 miles of river.

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METHODS AND MATERIALS

Specimens were collected from June 1965 to Jan 1967. Additional material was examined from a co tion made at New Athens on August 13, 1964.

Most collections were made from June thro

August when water levels were usually low. At Carlyle a few spring and fall collections were made and at the Sullivan station collections were made throughout the year.

The seine most commonly used was 12 feet long and 4 feet deep, and had 3/16-inch bar mesh. Greatest efficiency was achieved in riffle areas of moderate current. Pools up to 3½ feet deep were sampled by dragging the seine over the bottom.

Most collections were made during the day. For food studies, fish were collected both day and night on August 7, 1966, from the Sullivan station. Another day-night collection was made there on October 10, 1966.

In collections used in indicating habitat preference, the river's current, depth, and bottom materials, and the number of each species, were recorded for each seine haul. This permitted a rough quantitative comparison of habitats of the four darters.

Quantitative collections were made during August and early September in both pool and riffle habitats by poisoning, using emulsifiable rotenone. Block seines were used at the lower and upper ends of the station. Potassium permanganate was used below the station to oxidize the rotenone. All small fish were preserved. Upon completion of a collection the average depth, average velocity, bottom composition, and total area were recorded. Bottom types were classified as silt, sand, fine gravel, course gravel, rubble, or bedrock. Current was measured with a Gurley pigmy current meter, set 1 inch from the bottom unless otherwise stated. Turbidity was measured using a USGS turbidity needle.

Many specimens were handled in the field when making habitat comparisons and studying coloration. Some 167 *maculata,* 130 *phoxocephala,* 39 *caprodes,* and 52 *shumardi* were processed in the laboratory for total length, weight, and sex. Observations were made on gonad size, egg size, and egg counts. The presence of parasites was recorded.

Stomachs were analyzed for 274 specimens of *Perina.* Of these fish 71 *maculata,* 38 *phoxocephala,* and 9 *caprodes* were from Sullivan; 16 *maculata,* and 20 *phoxocephala* from Vandalia; 6 *maculata,* 32 *phoxocephala,* and 2 *caprodes* from Carlyle; and 13 *phoxocephala,* 5 *caprodes,* and 42 *shumardi* from the New Athens-Evansville area.

All organisms were washed from the stomach, grouped into families, and counted. When whole organisms were not present, heads were counted, since the head was usually the last portion of most organisms to be digested. When food items had been recently engulfed, the total wet weight of the stomach contents was taken and the percent of total weight was obtained for each group of organisms present. Intestine contents were also examined. The location of food in the digestive tract was often useful in determining the periods of feeding. Stomachs of some predatory fishes from darter habitats were examined.

Several scales were taken from the side of the body just above the lateral line at a point below the junction of the two dorsal fins. Scales were placed in a drop of water on a slide and read on a scale projector with magnification of 45X (described by Van Oosten 1923). The annuli (represented by a crowding of circuli) were found only on the anterior field. Measurements were made of the scale radius, and of the distance from the focus to each annulus, and were used, along with total lengths, in back-calculating the length of the fish at the end of each year of life.

Back-calculations of age at each annulus were analyzed using a SUPAC program on the IBM 7094 computer. A number of different regression lines were tested to determine which would give the best fit for scale radius-body length relationships. Because of greater variation in scale radius-body length relationships of larger fish, the logarithmic regression gave the best fit and was used in back-caculating lengths at each annulus.

DISTRIBUTION AND HABITAT

P. caprodes has the most extensive range of the four darters, occurring from southeastern New Mexico east to northwestern Florida and north to the Hudson Bay drainage. In Illinois it is found occasionally throughout the state (Smith 1965). In the Kaskaskia River it was rare in the headwaters, occasional at Arcola, reached its greatest abundance in the Sullivan to Shelbyville area, was fairly common through the Vandalia area, and then was occasional downstream to the New Athens area (Table 2 and Fig. 4).

In the area of the river from Sullivan to Shelbyville, *P. caprodes* was found in runs with moderate to fast current and medium to large gravel and rubble. The species has been reported in similar habitats in other parts of its range by Greeley (1927, 1928, 1929), Metcalf (1959), Blair (1959), and Trautman (1957). In the 1966 collection made with rotenone at the Eagle Creek station, nine individuals were taken in the pool, and six in the riffles. In the middle and lower portions of the river, most *P. caprodes* collected in riffles were young-of-the-year fish.

P. maculata also has a wide distribution occurring from the lower Mississippi north to upper Minnesota and east to the Lake Ontario region. In Illinois it is widely distributed in the eastern two-thirds of the state but is sporadic in western counties (Smith 1965). In the Kaskaskia, it was occasional in the headwaters, relatively abundant from Arcola to Eagle Creek, common through the Vandalia area, and then sporadic throughout the rest of the river (Table 2 and Fig. 4). This species is migratory, and was more abundant in the headwaters in winter and spring than in summer. Larimore, Childers, & Heckrotte (1959) found it to be one of the first to repopulate Smith's Branch after a drought.

In the Kaskaskia, *P. maculata* was usually found over a wider range of bottom types than the other darters studied. In riffles it was usually found in the deeper places where the current decreased. In the 1966

TABLE 2. — Quantitative data on *Percina* from three years of collections with rotenone. Numbers are the total numbers fish per acre of water. A zero indicates that the species was not collected in the sample. A dash indicates that no collection made.

Station Number and Location	Area, Acres[a]	*P. maculata*			*P. phoxocephala*			*P. caprodes*			*P. shumar*		
		'64	'65	'66	'64	'65	'66	'64	'65	'66	'64	'65	
1 Headwaters	0.16	–	–	19	–	–	0	–	–	0	–	–	
2 Arcola	0.20	274	363	35	16	10	0	16	16	0	0	0	
3 Sullivan-Bruce	0.27	231	337	122	0	143	159	38	77	26	0	0	
4 Eagle Creek	0.34	337	171	15	218	29	200	33	35	15	0	0	
5 Moore's Bridge	0.38	52	43	11	158	31	100	6	13	5	0	0	
6 Above Vandalia	0.53	3	11	25	142	24	15	2	0	0	0	0	
7 Below Vandalia	0.30	0	19	40	12	97	233	5	16	53	0	0	
8 Above Carlyle	1.46	–	1	2	–	0	0	–	0	0	–	0	
9 Below Carlyle	0.66	0	1	12	23	20	24	0	0	0	0	0	
10 Below New Athens	1.28	0	–	0	17	–	13	4	–	1	51	–	
11 Above Evansville	0.69	0	–	0	2	–	4	17	–	6	518	–	
12 Below Evansville	0.86	1	–	0	0	–	0	0	–	1	0	–	

[a] Area is given for 1966 collections.

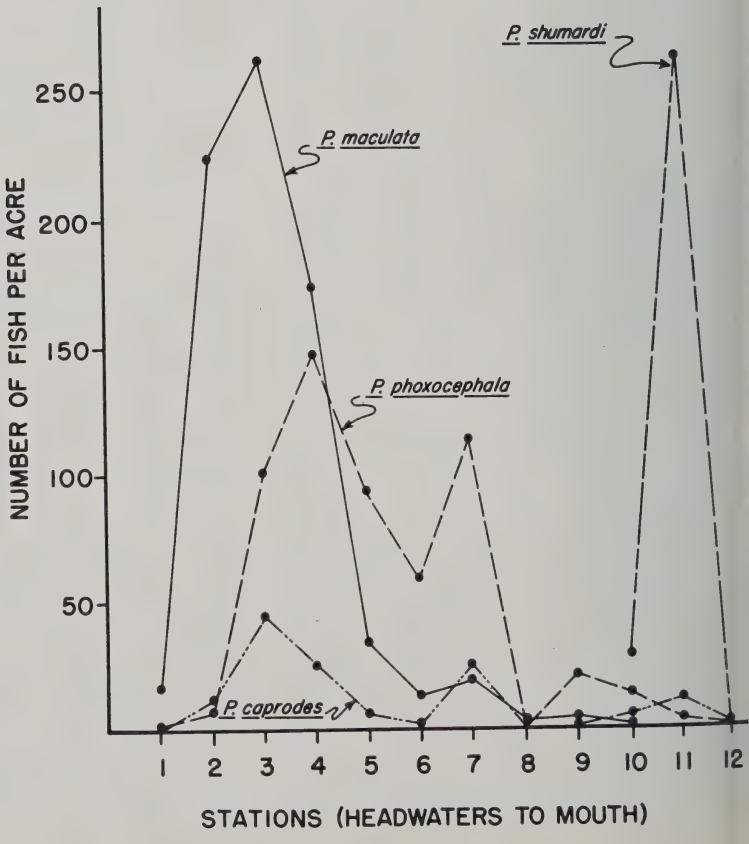

Fig. 4. — Average number of fish per acre, collected with rotenone from each station, during 3 years (1964–1966).

sample at Eagle Creek, nine individuals came from the pool and six from the riffles, the same numbers as for *P. caprodes*. In the Vandalia area *P. maculata* was often found around brush and logs where the current was slow. Variable habitat preference seemed to be generally characteristic, ranging from shallow, swift water over a hard bottom, often of rubble or rock (Greeley 1927, 1928, 1929) to sluggish water over muddy bottoms (Scott 1954).

P. phoxocephala has the most restricted range of the darters studied, being generally limited to the Midwest. It occurs occasionally throughout Illinois except in the extreme northeastern and southern portions of the state (Smith 1965). In the Kaskaskia it was rare in the headwaters, was found fairly abundantly from the Sullivan area to Vandalia, and was occasional throughout the rest of the river (Table 2 and Fig. 4).

It was found most often in the Kaskaskia over fine gravel with moderate to fast current in fairly shallow water, as has been reported in other parts of its range by Cross (1954, 1967), Deacon (1961), Metcalf (1959), Starrett (1950), and Trautman (1957). In the 1966 collection at Eagle Creek, 175 of the 200 *phoxocephala* collected were from the riffles. In the Carlyle area it was often absent from some of the gravel riffles and was collected most often over a rubble bottom. Its absence from gravel riffles at Carlyle may have been due to competition for both space and food with the abundant freckled madtom, *Noturus nocturnus*, and young channel catfish, *Ictalurus punctatus*.

P. shumardi is generally restricted to large rivers. It ranges from western and northern Ontario south to the coastal plain of Texas and east through much of the Ohio and Tennessee river drainages to western Lake Erie.

In Illinois this darter is distributed generally in the Mississippi River but is sporadic in the Illinois, Ohio, and Wabash rivers (Smith 1965). In the Kaskaskia it was found exclusively from the New Athens area south, where it was often abundant and usually outnumbered the other three species of *Percina* (Table 2 and Fig. 4). Forbes & Richardson (1920) found *P. shumardi* at Carlyle and Vandalia in the early 1900's, but it has not been collected from these stations since that time.

P. shumardi was collected commonly in areas of moderate current over rubble and large gravel. It was usually taken in deep riffles and chutes with only the young being found in shallower water (2 feet or less).

The abundance of these four darters at any station shows a great deal of yearly variation (Table 3). However, the general distribution of these *Percina* throughout the whole river remains about the same.

REPRODUCTION

Winn (1958*a*, 1958*b*) found *P. maculata* utilizing pools and raceways to spawn where it laid its eggs in coarse sand or fine gravel in water a foot or more deep. Petravicz (1938) found it spawning over sand and gravel in water a foot deep and of moderate current. The eggs are abandoned after fertilization.

In the Kaskaskia (Sullivan area), *P. maculata* was the first of the four species to enter the riffles in numbers in the spring. As early as March 13, 1966, females had enlarged urogenital papilla and gonads with up to 2,000 enlarged eggs. Gonad weight comprised about 17 percent of the body weight of adult females collected in March. Yearling females collected on April 18, 1966, had gonad weights ranging from 2 to 15 percent of the total body weight and egg counts ranging from 630 to 860. The larger of these yearling females probably spawned, but the small ones had very small eggs and would not have spawned at the end of their first year.

All four species of *Percina* spawn from April to June. In 1965, fertilized eggs of *P. maculata* probably hatched in early May and young ranged in size from 16 to 24 mm by June 8. In 1966, high waters apparently

TABLE 3. — Number of individuals of *Percina* taken in 4 years of collections with rotenone at the 12 stations. A dash indicates collection was made.

Station Number and Location	*P. maculata*				*P. phoxocephala*				*P. caprodes*				*P. shumardi*			
	'62	'64	'65	'66	'62	'64	'65	'66	'62	'64	'65	'66	'62	'64	'65	'66
Headwaters	–	–	–	3	–	–	–	0	–	–	–	0	–	–	–	0
Arcola	–	52	69	7	–	3	2	0	–	3	3	0	–	0	0	0
Sullivan-Bruce	8	67	101	33	34	0	43	43	1	11	23	7	0	0	0	0
Eagle Creek	7	91	53	5	8	59	9	68	1	9	11	5	0	0	0	0
Moore's Bridge	–	26	29	4	–	79	19	38	–	3	8	2	–	0	0	0
Above Vandalia	3	3	11	13	9	142	25	8	1	2	0	0	0	0	0	0
Below Vandalia	0	0	7	12	1	5	36	70	0	2	6	16	0	0	0	0
Above Carlyle	–	–	1	1	–	–	0	0	–	–	0	0	–	–	0	0
Below Carlyle	3	0	1	8	3	16	16	16	0	0	0	0	0	0	0	0
Below New Athens	0	0	–	0	4	17	–	16	0	3	–	1	6	51	–	12
Above Evansville	0	0	–	0	1	2	–	3	1	17	–	4	8	518	–	6
Below Evansville	0	1	–	0	0	0	–	0	2	0	–	1	3	0	–	0

interrupted much of the spawning and reproductive success was reduced from 1965 (Table 4).

Reproduction of *P. phoxocephala* was later than for *P. maculata*. When floods occurred around the first of June 1965, reproduction of *P. phoxocephala* was poor. In 1966, high water came in April and May but was lower by June. Reproduction was greatly improved over 1965 (Table 4).

The large range in size of yearling *P. phoxocephala* (34–57 mm on April 18, 1966) indicated an extended spawning period. Another indication was the condition of a few females collected in August; they still had enlarged ovaries. One 80-mm female collected below Carlyle as late as August 11, 1965, had about 330 medium to large eggs. At Vandalia on August 5, 1965, three females had enlarged gonads with eggs. Though most of these eggs showed resorption, one female had two milky white eggs in the urogenital opening. Gonad weight in these females comprised about 6 percent of the total body weight, whereas others taken at the same time had reduced ovaries which comprised less than 0.5 percent of the total body weight. No males collected in August showed enlarged testes.

Winn (1958*b*) reported *P. caprodes* spawning over gravel and small rubble in riffles and raceways with fast current. The eggs are partly buried in the gravel during fertilization and are then abandoned (Winn 1958*a*). In the Portage Lake outlet (Michigan) they spawned from April 1 to June 1. The fact that no *P. caprodes* were collected in spring in the Kaskaskia suggests that they were spawning in deeper chutes or pools where collecting was difficult. Young-of-the-year were collected on June 16, 1966, in the Carlyle area. One fish 29 mm and another 50 mm long may have represented two different broods, one in April and one in May.

P. shumardi spawned during April and May. Young collected on June 29, 1966, ranged in size from 36 to 43 mm in total length.

Annual gonadal changes were fairly similar in all of these darters. During the summer and early fall, the gonads were usually reduced in size. By October, the gonads began to increase in size, and body coloration became intensified. The gonads reached maximum development in spring when water temperature, water levels, and possibly photoperiod helped determine the time of spawning.

There is very little sexual dimorphism in the four species of *Percina*. Petravicz (1938) found that the ventral fins of male *P. maculata* were a little broader than those of the females. *P. shumardi* showed the greatest sexual dimorphism, the males having much longer anal fins.

TABLE 4. — Comparison of the number of young and adult *Percina* at the Sullivan and Eagle Creek stations. Fish are from the 1965 and 1966 collections made with rotenone.

	1965		1966	
	Young	Adult	Young	Adult
Sullivan				
P. maculata	55	46	28	5
P. phoxocephala	4	39	15	28
P. caprodes	4	19	1	6
Eagle Creek				
P. maculata	38	15	0	5
P. phoxocephala	3	5	56	12
P. caprodes	3	6	2	3

FOOD HABITS

Stomach analyses were made on 93 *P. maculata*, 103 *P. phoxocephala*, 36 *P. caprodes*, and 42 *P. shumardi*. A list of all the food organisms found and identified in stomachs is given in Table 5.

Food habits of both young and adult *P. maculata* at Sullivan were compared from spring (March–May), summer (June–August), fall (September–November), and winter (December–February) collections (Table 6). The greatest variety of organisms was eaten in the summer. Dipteran larvae and pupae (particularly chironomidae) were an important part of the diet during all seasons. Simulid larvae predominated in the spring and fall. Crustaceans were found in stomachs only during the summer and winter. Baetids made up the greatest volume of food in the summer.

Feeding intensity was heaviest in the spring. Stomach contents from three adult *P. maculata* collected on April 18, 1966, weighed 132 mg, 113 mg, and 112 mg, and were indicative of the generally full stomachs found at this time. Summer stomach contents usually weighed no more than 50 mg and in most cases less than 10 mg. Much or all of this difference in volume of food from spring and summer stomachs may be due to increased digestion rates in the summer.

Young *P. maculata* showed a rapid change in food habits from a diet predominantly of microcrustaceans to one comprised mainly of insect larvae. Eight young-of-the-year, ranging in size from 18 to 24 mm, collected on June 8, 1965, were already eating chironomid larvae and ephemerid nymphs, although Copepoda and Cladocera still predominated in the diet. The general difference in food habits between young-of-the-year and adults during the summer was a greater utilization of microcrustaceans and small insect larvae in young to greater utilization (particularly by volume) of Ephemeroptera nymphs and Trichoptera larvae in adults. Turner (1921) found no change in food habits of *P. maculata* that ranged in size from 34 to 57 mm.

Food habits of *P. maculata* at Vandalia and Carlyle were very similar to those in the Sullivan area, with baetid nymphs, chironomid, simuliid, and hydropsychid larvae predominating (Table 7).

TABLE 5. — Summary of food organisms found in four species of *Percina* from the Kaskaskia River in Illinois. The + symbol indicates that a particular family of food organisms was eaten. An X indicates that a particular species was identified from the stomach of the indicated species of darter.

	P. maculata	*P. phoxocephala*	*P. caprodes*	*P. shumardi*
iptera				
Chironomidae	+	+	+	+
Psectrocladius spp.	..	..	..	X
Psectrocladius nigrus	X	..	..	..
Pentaneura spp.	X	..	..	..
Tanytarsus spp. (larvae)	..	..	..	X
(pupae)	..	..	X	..
Chironomus (Dicrotendipes) spp.	..	..	X	X
Chironomus (Dicrotendipes) nervosus	..	..	..	X
Orthocladius spp.	X	..	..	X
Orthocladius thienemanni (?)	X	..	..	..
Polypedilum spp.	..	X	..	X
Chironomini (pupae)	X	..	..	..
Simuliidae	+	+	+	+
Ceratopogonidae	+	..	..	..
Rhagionidae	..	+	+	..
Anthomyiidae	+	..	..	..
Ephydridae?	..	+	+	+
hemeroptera				
Baetidae	+	+	+	+
Neocloeon alamance	..	X	..	..
Ameletus ludens	..	..	X	X
Baetis spp.	..	X	..	..
Heptageniidae	+	+	+	+
Heptagenia marginalis	X	X	..	X
Stenonema spp.	X	..	X	..
Heptagenia spp.	..	..	X	..
Caenidae	+	+	+	+
Caenis spp.	X	..	X	..
Tricorythodes spp.	X	..	X	..
Ephemeridae	..	+	..	..
Hexagenia limbata	..	X	..	..
choptera				
Hydropsychidae	+	+	+	+
Potamyia flava	..	X	..	..
Misc. "case builders"	+	+	+	+
coptera				
Perlidae	..	..	+	..
Neoperla clymene (?)	..	..	X	..
eoptera				
Elmidae	..	..	+	..
Stenelmis vittipennis	..	..	X	..
Haliplidae	+	..	..	..
niptera				
Notonectidae	+	..	..	..
onata				
ygoptera	..	..	+	..
tropoda				
ancylidae	..	..	+	..
Ferrissia spp.	..	..	X	..
stacea				
opepoda	+	..	+	+
ladocera	+	..	+	+
stracoda	+	..	..	..
embola	..	+	..	..
es eggs	+	+	..	+
cta eggs	+	..	+	..
t material	+	..	+	..

TABLE 6. — Seasonal foods of *P. maculata* at Sullivan. "Young" refers to fish in their first year of growth; "adult" fish are those 1 year of age or older. "Frequency" is the percent of the total number of stomachs examined (including those empty) containing the item listed. "Average number" is the average number of items found in stomachs which contained that item.

	Spring				Summer				Fall				Winter	
	Young (11)		Adult (4)		Young (23)		Adult (20)		Young (10)		Adult (3)		Young (5)	
	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.
Diptera	100	18.5	100	28.8	83	6.1	60	17.1	100	21.2	67	1	80	2.
Chironomidae	91	7.6	75	26.7	4	4	5	3	30	16.3	33	10	20	6
Simuliidae	55	2.2	25	4	30	2	30	2.3	30	1	..	..	20	1
Diptera pupae	..	..	..	..	..	..	..	..	10	1	..	..	..	
Diptera adults	..	..	25	1	..	..	..	..	..	..	..	..	..	
Anthomyiidae	..	..	..	..	..	..	5	5	..	..	..	..	20	1
Ceratopogonidae	..	..	..	..	57	10.5	60	10.8	60	2.7	67	16	20	1
Ephemeroptera	..	..	..	..	30	2.3	35	3.1	10	1	..	..	..	
Baetidae	..	..	25	1	9	2	10	1.5	..	..	..	..	..	
Heptageniidae	..	..	..	..	13	1	5	7	..	..	..	..	20	1
Caenidae	..	..	..	..	4	2	15	10	50	3.2	67	3	40	1
Miscellaneous	..	..	25	1	..	..	15	1	..	..	33	1	..	
Trichoptera	..	..	..	..	..	..	5	1	..	..	..	..	..	
Hydropsychidae	..	..	..	..	4	2	5	4	..	..	..	..	..	
"Case builders"	..	..	..	..	..	..	..	..	..	..	..	..	80	84
Coleoptera	..	..	..	..	65	25.9	30	5.7	..	..	..	..	40	2
Haliplidae	..	..	..	..	30	4	15	2	..	..	..	..	..	
Hemiptera	..	..	..	..	13	1	..	..	..	..	..	..	..	
Notonectidae	..	..	..	..	..	..	5	1	..	..	..	..	..	
Crustacea	..	..	..	..	..	..	10	3.5	10	1	..	..	..	
Copepoda	..	..	..	..	9	1.5	20	5.3	10	2	33	1	..	
Cladocera	..	..	..	..	4	2	5	1	10	1	..	..	..	
Ostracoda	..	..	..	..										
Fish eggs	..	..	..	..										
Insect eggs	..	..	..	..										
Sand grains	..	..	..	..										
Plant fragments	..	..	..	..										

In a comparison of summer food habits of *P. phoxocephala* in four areas of the river (Table 8), baetid nymphs, chironomid larvae, and hydropsychid larvae predominated as food items. Food habits were similar at all four stations, although there was increased utilization of baetids and hydropsychids at the lower stations. Hydropsychids made up 80 percent of the volume of food in seven adults collected at Vandalia, and 72 percent of the volume of food of six adults at Carlyle. Baetids made up the largest volume of food in young *P. phoxocephala* at Vandalia, demonstrating the difference in food habits of young and adults.

In a comparative study of the three species at Sullivan (Table 9), *P. caprodes* was found to eat the greatest variety of organisms and to feed on groups such as Plecoptera, Odonata, Coleoptera and Gastropoda that were rare or absent as food of other *Percina*. *P. caprodes* also utilized more chironomids, dipteran pupae, heptageniids, caenids, and hydropsychids than the other two species of *Percina* at Sullivan.

Feeding habits of *P. caprodes* were found to change from a high utilization of chironomid larvae and dipteran pupae in the young, to greater utilization heptageniid and caenid nymphs and hydropsychid larv in adults. In seven stomachs from adults collected August of 1965, heptageniid nymphs made up an erage of 73 percent of the total volume.

Food habits of *P. phoxocephala* at Sullivan w similar to those of *P. maculata;* however, *P. phoxo phala* utilized more hydropsychids than *P. macul* and more simuliids than *P. caprodes*.

Food organisms consumed by *P. shumardi* in lower river consisted primarily of chironomid and dropsychid larvae (Table 10). This darter utili fewer baetids than did the sympatric *P. phoxocep* but otherwise feeding habits of the two species w similar.

Time of Feeding

Darters were found to feed throughout the dayl hours. When the water was warm and digestive r were fast, estimates of feeding periods could be m On August 17, 1966, fish were collected from the S van station at five different times of the day and n

TABLE 7. — Summer foods of *P. maculata* at Vandalia and Carlyle. "Frequency" is the percent of stomachs examined containing the item listed. "Average number" is the average number of items found in stomachs which contained that item.

	Vandalia				Carlyle	
	Young (14)		Adult (2)		Young (6)	
	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.
Diptera						
Chironomidae	92.9	5.0	50.0	5.0	100.0	9.3
Simuliidae	28.6	5.8	100.0	7.5	16.7	1.0
Diptera pupae	7.1	3.0	..	..	..	..
Ceratopogonidae	7.1	3.0	..	..	..	..
Ephemeroptera						
Baetidae	78.6	8.2	100.0	43.5	16.7	13.0
Heptageniidae	..	..	..	..	16.7	1.0
Caenidae	7.1	3.0	..	..	..	..
Trichoptera						
Hydropsychidae	64.3	1.7	50.0	12.0	100.0	6.2
"Case builders"	7.1	1.0	50.0	2.0	..	..
Crustacea						
Copepoda	..	..	..	..	33.3	10.2
Cladocera	..	..	..	..	16.7	4.0
Fish eggs	..	..	..	..	16.7	2.0
Sand grains	..	..	..	..	33.3	2.0
Plant materials	7.1	65.0	50.0	16.0	..	..

to determine times of feeding. At night (2:00 AM), the stomachs and intestines of *P. maculata* and *P. caprodes* were empty, indicating that a number of hours had elapsed since those fish had fed. *P. maculata* collected at 7:30 PM had an average of 18 relatively fresh organisms in their stomachs, indicating that they had fed until darkness. *P. phoxocephala* collected at 2:00 AM still had a few heads of food organisms in their stomachs, and most of the intestines contained food, indicating that they may have fed at least for a while after dark. This was also borne out by a collection made on October 10, 1966, at 8:45 PM (a little more than 2 hours after dark). *P. phoxocephala* stomachs contained food while most *P. maculata* stomachs were empty or had just a few organisms in the posterior portions of the stomachs.

At all times feeding intensity was lower for *P. phoxocephala* than for the other *Percina*. The apparent extended feeding period of *P. phoxocephala* might compensate for this.

Food Selection

Turner (1921) believed that food preference was not a factor in the distribution, except locally, of Ohio darters. Pearse (1918) stated, however, that most fishes selected specific items from the available food supply and this might affect distribution. In a comprehensive study, Ivlev (1955, tr. 1961) stated that for the survival

TABLE 8. — Comparison of summer foods of *P. phoxocephala* from four localities from the upper to the lower river. "Frequency" is the percent of stomachs containing the item listed. "Average number" is the average number of items found in stomachs which contained that item.

	Sullivan				Vandalia				Carlyle				New Athens-Evansville			
	Young (11)		Adult (27)		Young (10)		Adult (10)		Young (12)		Adult (20)		Young (9)		Adult (4)	
	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.
Diptera																
Chironomidae	100.0	5.2	44.4	2.4	90.0	7.8	30.0	1.7	83.3	13.9	60.0	2.2	88.9	9.9	100.0	4.0
Simuliidae	36.4	5.0	18.5	5.2	30.0	1.7	20.0	1.0	8.3	2.0	..	..	11.1	1.0	..	..
Diptera pupae	..	..	7.4	1.5	10.0	1.0	..	..	8.3	3.0	5.0	1.0	11.1	1.0	..	..
Ephydridae	..	..	..	..	..	..	..	..	..	..	..	..	11.1	1.0	..	..
Rhagionidae	..	..	..	..	..	..	..	..	8.3	1.0	..	..	..	..	..	..
Ephemeroptera																
Baetidae	36.4	3.3	29.6	2.4	100.0	5.1	60.0	4.3	50.0	2.0	40.0	5.9	66.7	12.7	50.0	1.5
Heptageniidae	36.4	2.0	25.9	1.3	40.0	1.3	80.0	1.4	41.7	1.0	40.0	3.1	22.2	1.0	..	..
Caenidae	9.1	1.0	11.1	1.0	10.0	2.0	..	..	8.3	1.0	..	..	..	..	..	..
Ephemeridae	..	..	7.4	1.0	..	..	..	..	8.3	1.0	..	..	..	..	..	..
Miscellaneous	9.1	2.0	14.8	1.0	..	..	..	..	..	..	..	..	..	..	..	..
Trichoptera																
Hydropsychidae	36.4	4.0	44.4	4.3	70.0	1.9	100.0	7.6	50.0	3.8	100.0	7.2	88.9	6.4	100.0	18.0
"Case builders"	..	..	..	..	..	..	..	..	8.3	1.0	..	..	..	..	..	..
Fish eggs	9.1	1.0	..	..	..	..	..	..	8.3	22.0	5.0	1.0	22.2	1.5	..	..
Insect eggs	..	..	..	..	..	..	..	..	..	..	5.0	10.0	..	..	..	..
Sand grains	18.2	2.0	..	..	..	..	50.0	1.8	8.3	11.0	30.0	2.2	22.2	1.0	25.0	2.0
Plant material	..	..	..	..	..	..	..	..	..	..	..	..	11.1	1.0	..	..
Collembola	..	..	..	..	..	..	..	..	..	..	..	..	22.2	2.0	..	..
(Empty)	..		14.8		..		..		16.7		..		..		..	

TABLE 9. — Comparison of foods of young and adults of three species of *Percina* at the Sullivan station. "Frequency" is the percent of stomachs examined containing the item listed. "Average number" is the average number of items found in stomachs which contained that item.

	P. maculata				*P. phoxocephala*				*P. caprodes*			
	Young (43)		Adult (22)		Young (11)		Adult (27)		Young (7)		Adult (22)	
	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.	Freq.	Av. No.
Diptera	88.4	13.5	77.3	18.9	100.0	5.2	44.4	2.4	100.0	36.9	100.0	15.3
Chironomidae	34.8	8.5	22.7	18.6	36.4	5.0	18.5	5.2	..	..	13.6	4.3
Simuliidae	37.2	1.8	31.8	2.6	..	..	7.4	1.5	57.1	13.3	59.1	3.5
Diptera pupae	2.3	1.0	..	..	..	..	..	..	..	..	4.5	2.0
Diptera adults	..	..	..	..	..	..	..	..	14.3	1.0	..	..
Ephydridae	..	..	4.5	1.0	..	..	..	..	..	..	..	..
Anthomyiidae	..	..	..	..	..	..	..	..	..	..	9.1	1.0
Rhagionidae	..	..	4.5	5.0	..	..	..	..	..	..	..	..
Ceratopogonidae	41.9	7.8	54.5	12.1	36.4	3.3	29.6	2.4	57.1	3.5	36.4	3.3
Ephemeroptera	18.6	2.1	36.4	2.9	36.4	2.0	25.9	1.3	14.3	1.0	86.4	17.
Baetidae	2.3	2.0	9.1	1.5	9.1	1.0	11.1	1.0	42.9	3.3	86.4	6.
Heptageniidae	..	..	..	..	..	..	7.4	1.0	..	..	..	..
Caenidae	7.0	1.0	4.5	7.0	9.1	2.0	14.8	1.0	..	..	4.5	1.0
Ephemeridae	13.9	3.0	18.2	2.3	36.4	4.0	44.4	4.3	42.9	17.7	50.0	29.
Miscellaneous	..	..	13.6	1.0	..	..	..	..	..	..	18.2	1.
Trichoptera	..	..	..	..	..	..	..	..	..	..	13.6	2.
Hydropsychidae	..	..	..	..	..	..	..	..	28.6	1.0	..	..
"Case builders"	..	..	..	..	..	..	..	..	28.6	2.0	18.2	1.
Plecoptera	..	..	..	..	..	..	..	..	..	..	..	..
Odonata	..	..	4.5	1.0	..	..	..	..	..	..	..	..
Zygoptera-Coeragrionidae	..	..	..	..	..	..	..	..	57.1	7.0	59.1	6.
Coleoptera	..	..	..	..	..	..	..	..	..	..	..	..
Elmidae	..	..	..	..	..	..	..	..	42.9	4.3	9.1	1.
Haliplidae	..	..	4.5	1.0	..	..	..	..	57.1	1.8	13.6	1
Gastropoda	..	..	..	..	..	..	..	..	..	..	..	..
Ancylidae	..	..	..	..	..	..	..	..	..	..	..	..
Crustacea	32.6	27.2	27.3	5.7	..	..	..	..	..	..	13.6	27
Copepoda	16.3	4.0	13.6	2.0	..	..	..	..	57.1	5.5	63.6	6
Cladocera	4.7	1.5	..	..	..	..	..	..	..	..	22.7	1
Ostracoda	..	..	4.5	1.0	9.1	1.0	..	..	..	..	..	..
Fish eggs	2.3	1.0	9.1	28.0	..	..	..	..	..	..	..	..
Insect eggs	7.0	1.7	22.7	4.4	18.2	2.0	..	..	..	..	..	..
Sand grains	4.7	1.5	4.5	1.0	..	..	..	..	14.8		..	..
Plant material	..	..	..	..	..	..	14.8					
(Empty)												

of an overwhelming majority of animals, biotic factors were of decisive importance and that, among these biotic factors, feeding conditions occupied an exceptional position. He found definite preference/avoidance patterns in food habits of certain fish and noted that a decrease in need for food resulted in increased selectivity for preferred forms of food.

There was some evidence of selective feeding in species of *Percina*. Elmid beetle adults and stonefly nymphs which were often abundant in riffles were generally avoided by the darters. Also, *P. maculata* took a preponderance of chironomids and simuliids in the spring, even though other groups of food organisms were common. Certain groups of organisms (such as Chironomidae) made up an important part of the diet in all *Percina* studied although different species of larvae were eaten in different habitats and in differe sections of the river.

GROWTH AND POPULATION STRUCTURE

All fish were aged by the scale method. Back-calc lations of length at each annulus were made from t logarithmic regression of scale length to body leng The following regression equations were used: *P. mac lata* (Log Y = -0.3885 + 1.0449 Log X), *P. phoxoc phala* (Log Y = -0.3530 + 1.0166 Log X), *P. caproc* (Log Y = -0.8150 + 1.2654 Log X), and *P. shuma* (Log Y = -0.1229 + 0.9397 Log X), where Y = times the anterior radius of the scale in millimet and X = total length of the fish in millimeters.

Length-weight relationships were determined by

Table 10. — Summer foods of *P. shumardi* at New Athens nd Evansville. "Frequency" is the percent of stomachs examned containing the item listed. "Average number" is the verage number of items found in stomachs which contained hat item.

	Young (30)		Adult (12)	
	Freq.	Average Number	Freq.	Average Number
iptera				
Chironomidae	60	20.6	67	2.5
Simuliidae	3	1.0	8	2.0
Diptera pupae	13	2.3	25	1.0
Ephydridae	..	..	8	1.0
phemeroptera				
Baetidae	10	1.0	17	1.0
Heptageniidae	7	1.5	17	1.0
Caenidae	3	1.0	..	..
Miscellaneous	3	1.0	..	..
richoptera				
Hydropsychidae	43	11.9	92	10.3
"Case builders"	3	1.0	..	..
rustacea				
Copepoda	7	13.0	..	..
Cladocera	7	4.5	..	..
sh eggs	10	5.0	8	4.0
nd grains	7	5.5	8	11.0
mpty)	23	..	..	..

the formula Log W = Log a + n Log L, where W = eight, L = length, and a and n are constants (Lagler 56). The following equations were found for each the four species: *P. maculata* (Log W = -5.7934 + 4207 Log L), *P. phoxocephala* (Log W = -5.2443 + 1332 Log L), *P. caprodes* (Log W = -6.2807 + 3.6412 g L), and *P. shumardi* (Log W = -5.6099 + 3.3701 g L). *P shumardi* showed the fastest increase in eight with length and was the most robust of the ur species. *P. caprodes* was by far the largest of the ur species of *Percina*.

Early growth of all darters was rapid and by the d of the first year they had reached 60–70 percent their total length. Most of the growth occurred m June through mid-September, as was found, for ample, for *P. maculata* in 1965 (Fig. 5).

In their second year of life, the males of all four cies averaged slightly larger than females, but the ference in growth between males and females (Fig.) was not statistically significant. Raney & Lachner 43) found that the males of *Etheostoma olmstedi* w faster than the females. In the latter as well as many other species of darters having faster-growing les, the males guard a territory. In *P. maculata* the le does not guard a territory and the sexes attain al lengths (Petravicz 1938).

Rate and pattern of growth of *P. shumardi* were ilar to those of *P. maculata* (Table 11). Growth *P. caprodes* was faster than growth of the other three

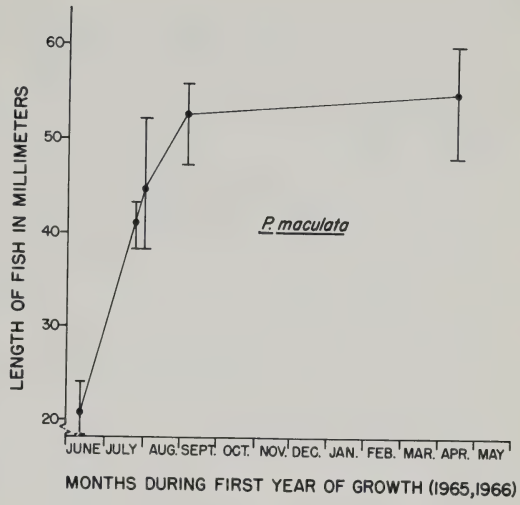

Fig. 5. — Early growth of *P. maculata* from June 1965 to April 1966. Line represents average lengths. The length range is shown for each of five collections.

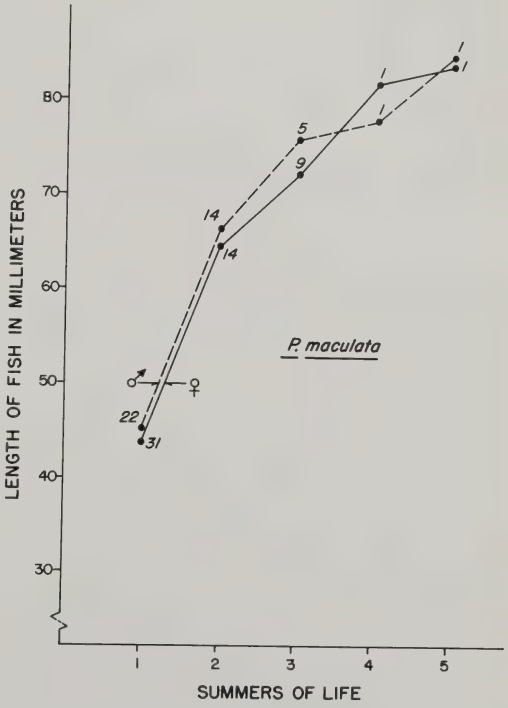

Fig. 6. — Growth of *P. maculata* throughout its life. Fish are from August 3, 1965 rotenone collection at Sullivan. The sexes are shown separately and actual numbers used in the averages for each year-class are shown.

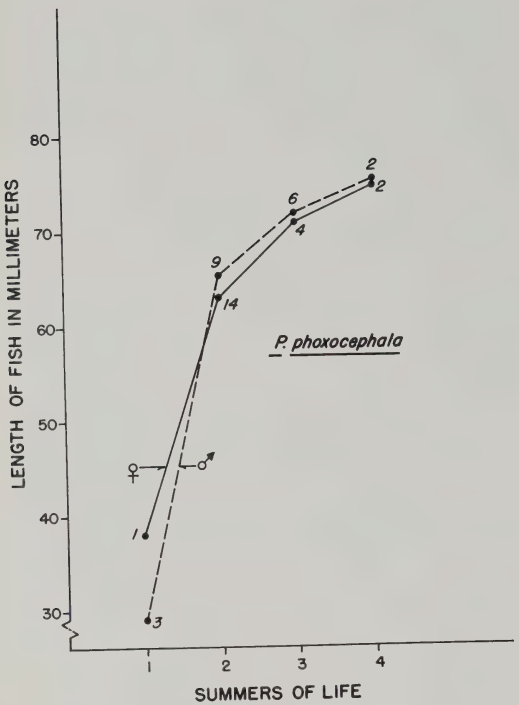

Fig. 7. — Growth of *P. phoxocephala* throughout its life. Fish are from the August 3, 1965 rotenone collection at Sullivan. The sexes are shown separately and actual numbers used in the averages for each year-class are shown.

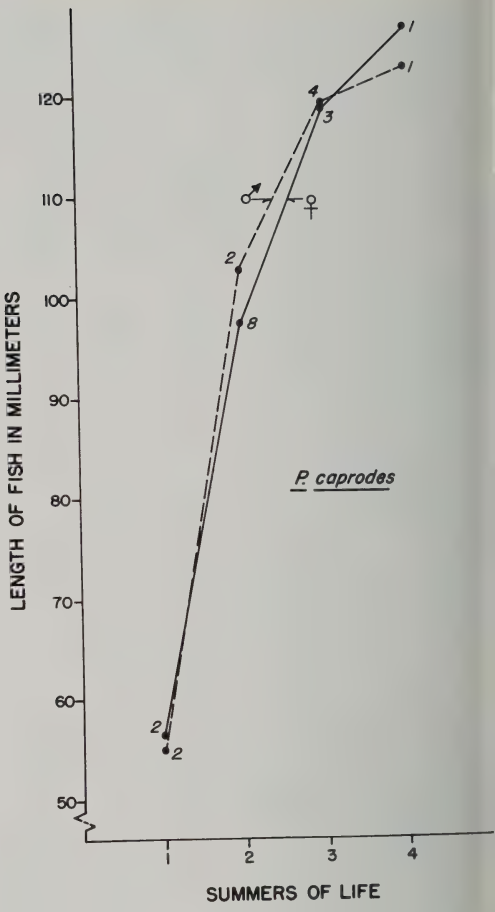

Fig. 8. — Growth of *P. caprodes* throughout its life. Fi
are from the August 3, 1965 rotenone collection at Sulliva
The sexes are shown separately and actual numbers used in t
averages for each year-class are shown.

species, and this species averaged 71.5 mm in total length at the end of the first year. *P. phoxocephala* were smaller than *P. maculata* at the end of the first year, possibly because the *P. phoxocephala* bred later in the spring. In Boone County, Iowa, Karr (1964) found that *P. maculata* grew faster throughout their life span than did *P. phoxocephala*. The mean calculated lengths at the end of the first year were 34.1 mm for *P. phoxocephala* and 34.7 mm for *P. maculata*. My data showed that during their second and third years of life, *P. phoxocephala* grew slightly faster than *P. maculata*. Also, growth for both of these species was much faster in the Kaskaskia, where *P. phoxocephala* averaged 45.3 mm and *P. maculata* 50.9 mm at the end of the first year.

Growth for *P. phoxocephala* was compared at Sullivan and Carlyle. Three-year-old fish showed slightly faster growth at Sullivan, but 1- and 2-year-old fish were larger at Carlyle. The differences found in 1-year-old fish at Sullivan and Carlyle in 1965 were not significant. The growing season was probably somewhat longer and spawning earlier at Carlyle, but the Sullivan area provided a more favorable habitat for this species.

The oldest individuals found were two *P. maculata* collected in August, 1965 at Sullivan which were their 5th year of life. No 4-year-old fish were fou in any of the other three species. Very few of th *Percina* live past their 3rd year.

The population structures of these darters var with the species' abundance and its success in reprod tion. Yearly changes in population structure at a stat were sometimes quite great, as shown in Tables 2 a 3. In 1965, the population of *P. maculata* at Sulliv was composed of approximately 50 percent young-the-year. Further downstream the smaller populati of this species were comprised mainly of young (F 10). Only *P. maculata* and *P. phoxocephala* were ab dant enough to permit population comparisons at three main collecting stations (3, 6, 9).

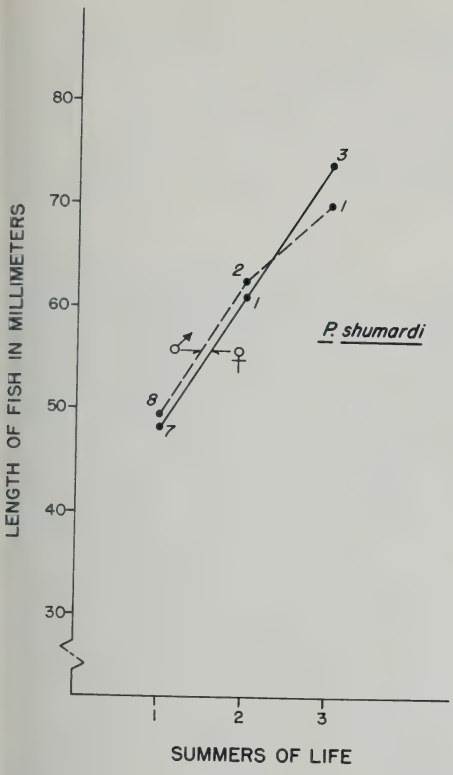

Fig. 9. — Growth of *P. shumardi* throughout its life. Fish e from the August 13, 1964 rotenone collection at New Athens. ie sexes are shown separately and actual numbers used in the erages for each year-class are shown.

Table 11. — Weighted mean calculated total lengths and growth increments for *Percina* collected from June 1965 to June 1966[a].

Age at Last Annulus	Number of Fish	Average Calculated Total Length in Millimeters at Indicated Year of Life I	II	III	IV
P. maculata					
4	4	44.4	58.6	68.3	78.7
3	3	46.7	61.0	70.9	
2	19	49.3	64.7		
1	44	52.4			
Weighted mean		50.9	63.3	69.4	78.7
Increments of Growth		50.9	12.4	6.1	9.3
P. phoxocephala					
3	7	43.6	59.0	67.6	
2	20	43.6	61.2		
1	39	46.4			
Weighted mean		45.3	60.6	67.6	
Increments of Growth		45.3	15.3	7.0	
P. caprodes					
3	2	71.5	100.0	121.5	
2	8	72.9	106.7		
1	11	70.4			
Weighted mean		71.5	105.9	121.5	
Increments of Growth		71.5	33.9	16.1	
P. shumardi					
2	3	46.3	64.9		
1	8	49.4			
Weighted mean		48.6	64.9		
Increments of Growth		48.6	16.3		

[a] Six of the *P. shumardi* were collected in August, 1964.

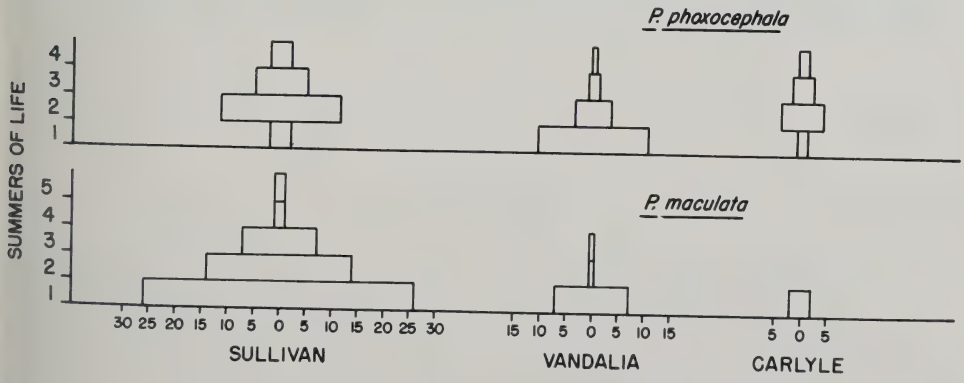

Fig. 10. — Population structure of *P. phoxocephala* and *P. maculata* at three stations (from collections with rotenone, Au-, 1965). Horizontal scale represents the actual number of fish in each year-class.

The small number of young *P. phoxocephala* in the Sullivan area in 1965 appeared to be the result of high waters during the breeding season. In the Carlyle area there were more *P. phoxocephala* adults than young. Part of the population here may have represented an influx from more favorable areas. Reproduction was poor in this section of the river and mortality of young may have been high.

P. phoxocephala in the Vandalia area may have spawned before the floods occurred in early June of 1965. This was the only area where reproduction was successful for this species in 1965.

LIMITING FACTORS

Stream size is an important factor in the distribution and abundance of the four darters in this study. *P. maculata* is generally most abundant in small rivers. Larimore & Smith (1963) found for Champaign County, Illinois, that this species reached its greatest abundance in streams with 4–8 square miles of drainage. *P. phoxocephala* and *P. caprodes* are found most abundantly in moderate-sized rivers. Probably the riffle-pool ratio of a moderate-sized river plus a variety of habitats make this size of stream most favorable. *P. shumardi* is generally limited to large rivers.

Stream gradient also appears to be an important factor. *P. maculata, P. phoxocephala,* and *P. caprodes* all reach their greatest abundance in the area from Sullivan to Shelbyville where the gradient is one of the highest in the river (Fig. 3 and 4).

Type of bottom may be an important limiting factor, particularly during the breeding season. Winn (1958*a*, 1958*b*) found that both *P. maculata* and *P. caprodes* used sand and gravel in which to lay their eggs. Long stretches of silt bottom pools (such as at stations 8 and 12, Fig. 2) in the middle and lower sections of the Kaskaskia probably limited the distribution of these darters.

The timing of floods also is a limiting factor. Starrett (1951) found that the usual high river stages in May and June limited the abundance of early spawning species in the Des Moines River and perhaps postponed spawning of some species of fish. The effects of the time of floods on reproduction are shown in Table 4. Floods also mean high turbidity and possible destruction of eggs during the breeding season.

Competition may be important in limiting numbers of individuals, particularly at high population levels. Food analyses of the freckled madtom, *Noturus nocturnus* and of young channel catfish, *Ictalurus punctatus,* indicate that during the summer they may be competing with *P. phoxocephala* not only for food but for space in the limited riffle areas at Carlyle.

Human alteration of the river has apparently affected at least the local distribution of these darters. Dredging and straightening of the channel has occurred in the headwaters and is now being carried out in the lower river. Carlyle Reservoir was partially filled before the completion of this study and the Shelbyville Reservoir was scheduled for completion later in 1970. Pollution is important at times throughout the length of the river. Industrial pollution from a chemical plant near Tuscola has occasionally killed fish for many miles downstream. Pollution from fertilizer companies has also been responsible for a few fish kills. All of the above factors have affected the abundance of *Percina* in the area of our studies.

PREDATION AND PARASITISM

No evidence of predation on these darters was found in the Kaskaskia River. Many stomachs of predatory fish were examined, including the largemouth bass, *Micropterus salmoides*; black crappie, *Pomoxis nigromaculatus;* white crappie, *Pomoxis annularis;* green sunfish, *Lepomis cyanellus;* rock bass, *Ambloplites rupestris;* and grass pickerel, *Esox americanus;* and the only darters found were a few specimens of the johnny darter, *Etheostoma nigrum.*

Two species of external parasites were found on three of the *Percina* studied. These included a small leech, *Illinobdella moorei* (?), and the copepod parasite *Lernaea* sp. There appeared to be very few internal parasites although a few nematodes were found in the stomachs.

The incidence of external parasites (excluding small trematodes) appeared to increase toward the end of the summer and early fall. No parasites were found on darters during the spring, but in the August, 1965 collection with rotenone at Sullivan 11 percent of the *P. maculata,* 15 percent of the *P. phoxocephala,* and 2 percent of the *P. caprodes* were affected with external parasites. Most darters had from one to four leeches on the caudal fin, although a few leeches were also found on the pelvic, pectoral, and anal fins. Copepod parasites were much less common and were usually found at the base of the soft dorsal fin.

No parasites were found on darters collected in the lower river.

Copepod parasites appeared to do the most damage as areas of the back where these parasites were found were often soft and infected. Very little external harm was done by leeches, although some fins were slightly damaged.

HYBRIDIZATION

In the Kaskaskia River, hybridization appeared to be very rare between members of the genus *Percina*. However, in the 1965 rotenone collection from the Sullivan area, two individuals were found which were hybrids of *P. maculata* x *P. phoxocephala.* Their identification was verified by Milton B. Trautman of Ohio State University, and they are now in the Ohio State collection (catalog number OSM 14019).

The two hybrids belonged to two different year classes. The first individual was 63 mm in length

veighed 2.22 grams, and was in its second year of fe. It looked superficially like *P. maculata* except for aving 12 dorsal spines and 12 lateral blotches similar o those of *P. phoxocephala*. The second individual as 75 mm, weighed 4.25 grams, and was in its third ear of life. It looked superficially like *P. phoxocephala* ith an orange band on the spiny dorsal. However, had 14 dorsal spines, 9 lateral blotches, and a large ardrop similar to *P. maculata*.

Most hybrid *Percina* that have been reported in the literature have *P. caprodes* as one parent. Trautman (1948) found that in low-gradient streams entering Lake Erie, ecological barriers which separated spawning *P. caprodes* and *P. maculata* in moderate-gradient streams were broken down, leading to hybridization. In the Kaskaskia at Sullivan, high and turbid waters during the breeding season may have been the main factor leading to hybridization.

Station 3 area of the Kaskaskia River, just below the mouth of Jonathan Creek near Sullivan, Illinois.

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A Synopsis of Common and Economic Illinois Ants, with Keys to the Genera (Hymenoptera, Formicidae)

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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION

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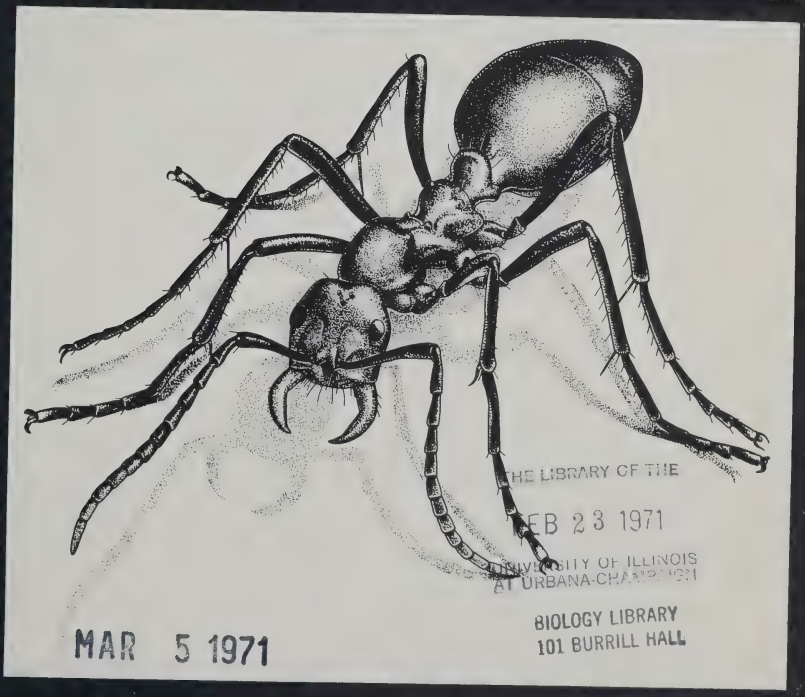

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A Synopsis of Common and Economic Illinois Ants, with Keys to the Genera (Hymenoptera, Formicidae)

Herbert H. Ross, George L. Rotramel, and Wallace E. LaBerge

TO THE ILLINOIS HOMEOWNER, gardener, or farmer, ants are probably the best known of all insects. They invade houses in search of food, hollow out house timbers to make nests, make mounds and bare spots in gardens and lawns, tend aphids that injure some of our crops, and the more pugnacious ones bite picnickers. However, ants that intrude upon our privacy are not the only ones living in Illinois. Many live in the house, in the garden under stones, or in the soil, and they forage chiefly at night. Many other species inhabit woodlands, some living in the ground, others in rotten logs, and still others in dead trees.

To date over 90 different kinds or species of ants have been taken in Illinois. Another 20 are known from neighboring states and will likely be found in Illinois with further collecting. These midwestern ants are classified into genera and these are grouped into six large categories called subfamilies. A seventh subfamily is more southern and western in distribution. These seven subfamilies constitute the North American representatives of the family Formicidae, which contains several thousand different species in the entire world.

Although superficially ants may look much alike, those belonging to different genera and species exhibit a remarkable number of differences in such characters as the shapes of the mandibles, sizes of the eyes, projections on the body, and contours of various parts. These characters are most marked between the genera. The species within many genera are frequently difficult to diagnose, and many complexes have not yet been thoroughly studied. As a result, it is not practical to give identification characters for every species occurring in Illinois. The genera and certain of the common and economic species can be identified readily, and these are the units that are treated in this synopsis, intended as a useful guide to the householder, gardener, farmer, and hiker.

LIFE HISTORY

All ants are social insects living in colonies or nests, and they have evolved a highly developed social pattern associated with the production and rearing of the young and the maintenance of the nest.

Developmental Stages

Ants belong to the large group of insects that have four distinctive stages in the life history: (i) the egg (ii) the larva, (iii) the pupa, and (iv) the adult, the latter represented by males, females, and workers (Fig. 1). Typical males and females have well-developed wings and sexual organs; the workers are much smaller adult stages that lack wings and sexual organs and differ from the winged adults in many details of morphology.

A typical ant nest centers around a queen, a female that has been fertilized and lost its wings. The queen stays in the nest and lays eggs that hatch into larvae. The larvae are whitish, legless maggots, somewhat egg-shaped but tapered toward the head end. They are completely helpless and must be moved about in the nest and fed by the adult ants. When full grown, the larvae transform into whitish pupae, the transformation stage between larva and adult. Some larvae spin cocoons around themselves before pupating, but some do not. The pupae also are helpless. If the nest is badly disrupted, the workers will carry the larvae and pupae out of the nest to hiding places in the soil or under stones. In nests with an active queen, the larvae usually develop into workers or certain workerlike forms.

The eggs, larvae, and pupae are cared for by the workers, who handle the immature stages inside the nest and forage for food outside the nest. The workers obtain enough food for themselves, the queen, and the growing larvae. Most of the larvae grow up to be workers. When these workers are mature, they take over their activities of foraging for food and feeding the queen and the larvae, collectively called the brood. The development from egg to adult takes several weeks.

Castes and Their Duties

Depending on the species, a nest or colony may consist of several hundred to many thousands of individual ants, including a considerable number of different forms or castes in addition to the queen. The commonest caste is called the worker, and these may be of two sizes; the smaller are minor workers and the larger are major workers. In the major worker the head is considerably larger in proportion to the remainder of the body than in the minor worker.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. The authors are one-time colleagues in the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Herbert H. Ross was formerly Assistant Chief of the Survey and Head of that section, George L. Rotramel was formerly a Technical Assistant in that section, and Dr. Wallace E. LaBerge is a Taxonomist in that section. Dr. Ross is now Professor of Entomology, University of Georgia, Athens. Mr. Rotramel is completing work for the Ph.D. degree in the Department of Entomology and Parasitology, University of California, Berkeley.

COVER ILLUSTRATION: A worker of *Polyergus lucidus*, the pale slave-making ant. Drawn by Mrs. Ann Prickett.

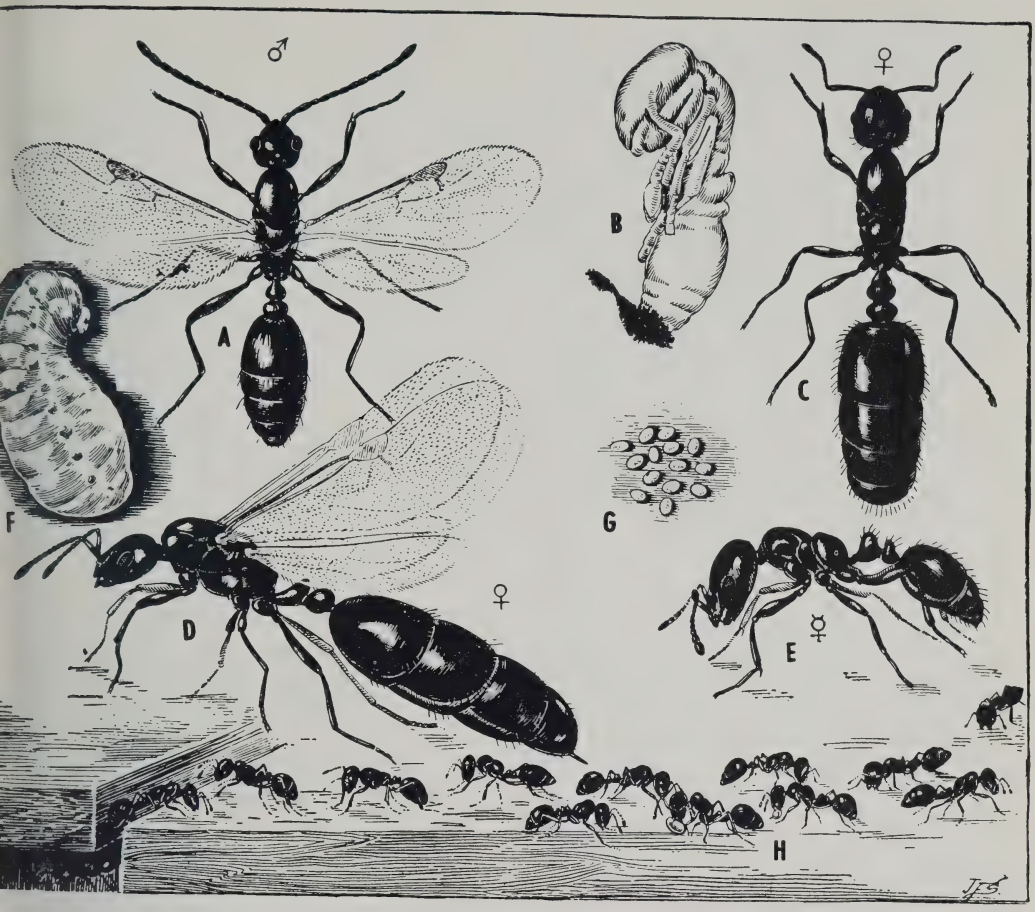

Fig. 1.—The little black ant, *Monomorium minimum*. *A*, male; *B*, pupa; *C*, female; *D*, female with wings; *E*, worker; *F*, larva; , eggs; *H*, group of workers in line of march. *A* to *G* much enlarged; *H*, about three times natural size. (From USDA)

me kinds of ants an even larger type of worker, the ldier, is present. The soldiers are very much larger an any of the other workers and usually have ex- emely long mandibles armed with sharp teeth. The imary function of the soldier caste is to protect the st; the soldiers do not take care of the brood. In me ant species individuals that look like soldiers because their larger eyes and much enlarged heads are tually specialized forms that crack plant seeds gathered r food. These nutcrackers are sometimes called the iller caste. Ants in other regions have evolved differ- t castes that are modified workers; that is, they never ve wings and cannot reproduce. All worker and ldier castes are females.

olony Formation

At specific times of the year (different times for ferent species) a large number of winged males and females are produced in each colony. These winged ants appear to take no part in the colony activities except for being fed. After they have matured in the nest, these winged forms fly out in great swarms, and it is during these flights that the males and females mate. The males take no further part in the history of the nest, but the fertilized winged females alone start new colonies. The males die soon after mating, usually by being devoured by birds, other ants, or predaceous insects.

Colony formation is extremely interesting. The fertilized female first nips off her wings, then burrows into wood or soil, makes a small cavity, and begins laying a few eggs. When these hatch into the first larvae of the colony, the female feeds them by regurgitation. The food stores used by the female are her fat bodies, formed while she was maturing in the parent nest, and the large wing muscles that are digested

by internal body fluids and converted into food. These first larvae tended by the queen develop into workers. As soon as these workers are mature, they start to forage, and from then on they and not the queen provide food for the colony.

Caste Development

One of the most interesting questions concerning ants is, why does one egg develop into a worker, another into a soldier, another into a winged, reproductive queen, and yet another into a winged, reproductive male? Entomologists who study ants have been sure for some time that some regulatory system determines the number of members of each caste produced within a colony. However, the mechanisms of this regulation are not clearly known as yet. The males arise from unfertilized eggs. This is true also of all ant relatives such as wasps and bees. The queens and worker castes develop from fertilized eggs. When an ant queen mates, she receives enough sperm to last her entire lifetime and keeps it stored in special glands inside her body. The major factor in caste formation, therefore, is the control of the development of fertilized eggs and does not involve heredity directly.

The clue to the differential development of the eggs seems to be found in certain feeding habits. When a worker feeds a larva or the queen or a soldier, the worker licks the body of the individual it has just fed. Apparently the bodies of these creatures exude certain secretions that are sought and enjoyed by the workers. It is believed that these secretions are actually hormones that control the behavior of the workers, primarily influencing the kind of food that they feed to the larvae. It has been found that larvae fed a high-protein diet develop into soldiers, whereas those fed a low-protein diet develop into workers. Presumably, similar dietary differences will cause a larva to develop into a reproductive queen.

TERMINOLOGY

The anatomy of ants differs in several respects fro those of many other insects such as grasshoppers an beetles. As a result, several terms used in the followin keys may be unfamiliar to the general entomologist. T clarify these terms, many of them are indicated for th worker and queen caste in Fig. 2 and 3. Others ar listed in the short glossary below.

The most important morphological difference b tween ants and many other insects concerns the div sions of the thorax and abdomen. In ants (and a other Hymenoptera) the first segment of the abdome has become consolidated into the last or third segmer of the thorax and forms an indistinct dorsal plate calle the epinotum. This epinotal area sometimes bears di tinctive spines, epinotal spines. The main bulk of th abdomen (called the gaster) is joined to the thora epinotum by a constricted and often beadlike narro portion called the petiole, which may consist of one two segments (the second and sometimes third tr segments of the abdomen). Unless one is referring sp cifically to the epinotal area, the epinotum and thora together are usually referred to simply as the thora

Abbreviated Glossary

clypeus—The "upper lip" of the front of the he (Fig. 3).

dorsum—The upper surface or top.

dorsal—Pertaining to the upper surface or top.

frontal carina—A ridge of the head just to the mes side of the base of the antenna; this may be elevat or form an overhang over the base of the antenn

funicle—The many-segmented portion of the anten beyond the scape or basal segment.

mesal—On or toward the midline of the body.

node—A projection or elevation on the dorsal surfa of one of the segments of the petiole.

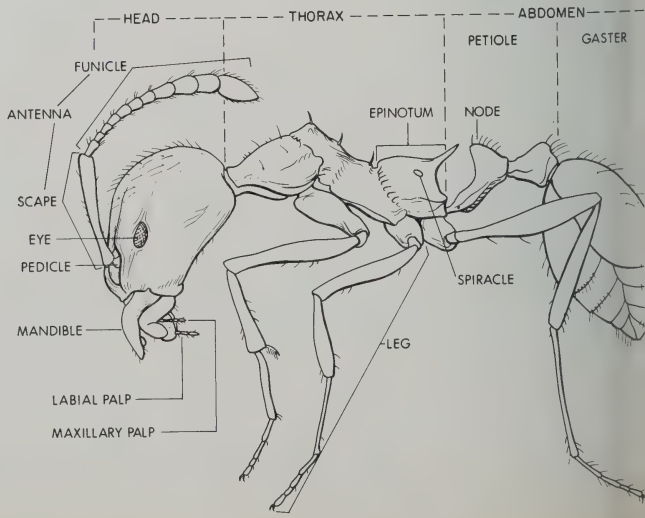

Fig. 2.—Worker ant of the genus *Aphaenogaster*, side view, showing terms used for diagnostic parts.

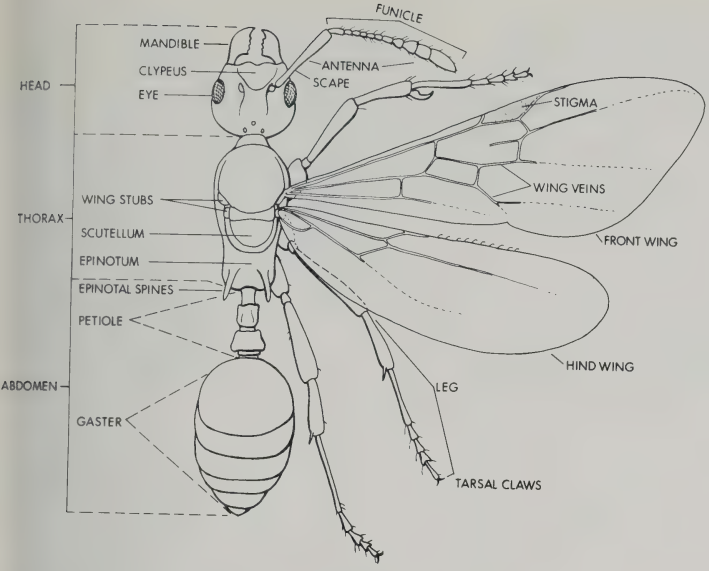

Fig. 3.—Winged female ant of the genus *Aphaenogaster*, dorsal view, showing terms used for diagnostic parts.

petiole—One of the small segments between the thorax and gaster. (If an ant specimen dies with the gaster elevated, the petiole and its structures may be difficult to see, in which case the specimen should be relaxed and the gaster depressed until the entire body is about level.)

scape—The first segment of the antenna. (When measuring this structure, one should not count the small socketlike end piece that actually articulates with the head.)

sclerite—Any area of the body set off by ridges, grooves, or membranes.

scrobe—A long, hollowed-out area on the head above the insertion of the antenna into which the antenna folds when in repose.

striae—Minute, ridgelike ornamentations of the surface.

suture—Any division between two sclerites.

venter—The underneath side.

ventral—Pertaining to the underneath side.

DIAGNOSIS OF ANTS AND TERMITES

Ants are members of the insect order Hymenoptera, which includes the sawflies, wasps, bees, and ants. Ants resemble some of the wasps, especially those having wingless forms that may resemble worker ants very closely in general appearance.

Ants may be differentiated from wasps by the ants having one or two segments forming a distinct petiole between the thorax and the gaster, each segment of his petiole produced dorsally into an enlargement or node (Fig. 1 and 2). Some of the wasps have a petiole, but none of them has one bearing a dorsal node.

Ants are also confused with termites, often called white ants, because termites also live in large colonies. Ants and termites may be differentiated as follows:

Winged or dark-bodied forms having the abdomen attached to the thorax by a narrow waist or petiole (Fig. 1); whitish, soft-bodied forms (larvae and pupae) found in the nest are grublike, nonambulatory, and often without legs ..... **ants**

Winged and dark-bodied forms having the abdomen joined broadly to the thorax; pale forms found in the nest all have well-developed legs and are ambulatory (Fig. 4) ..... **termites**

Termites constitute the insect order Isoptera, close relatives of cockroaches. Even the youngest stages have legs and are active. If a nest is disturbed, the older individuals do not carry the younger ones to a hiding place. Termites are not discussed further in this synopsis.

If an ant nest is disturbed, the worker ants carry the inactive larvae and pupae to a hiding place.

KEY TO ANT CASTES

The castes of ants may be identified by the following key. In this key the soldiers, nutcrackers, and both major and minor workers are keyed out together under "workers."

1. Tip of abdomen with a set of clasping structures that may be partially or completely retracted (Fig. 16*P*); wingless or with wings, but never with wing stubs ..... **males**

   Tip of abdomen without clasping structures, sometimes with a sharp sting (Fig. 7*E* and *H*) or a small cone having a ring of minute hairs (Fig. 6*D*); wingless or having wings or wing stubs . . 2

2. Having either wings (Fig. 3) or wing stubs that are visible on the sides of the thorax where the wings have been broken off; dorsum of thorax having several transverse or curved sutures between bases of wings or wing stubs, these sutures

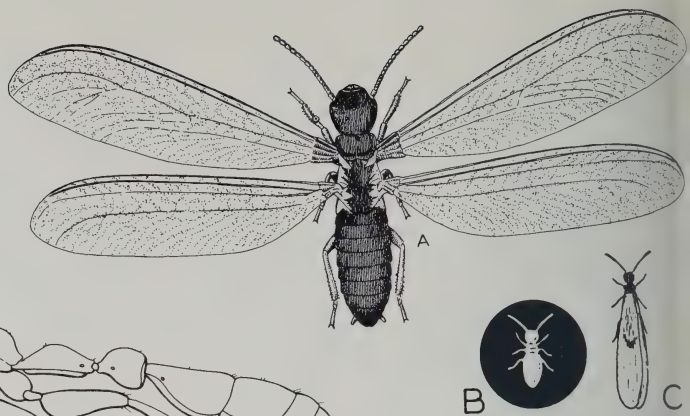

Fig. 4 (Right).—A common Illinois termite, *Reticulitermes flavipes*. *A*, winged queen; *B*, worker nymph; *C*, winged queen. *B* and *C* are natural size. (From Illinois Natural History Survey Circular 39)

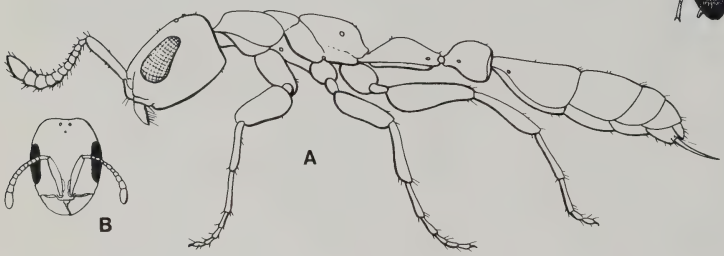

Fig. 5 (Left).—Worker of *Pseudo myrmex*. *A*, side view; *B*, fron view of head (at right angles t greatest length).

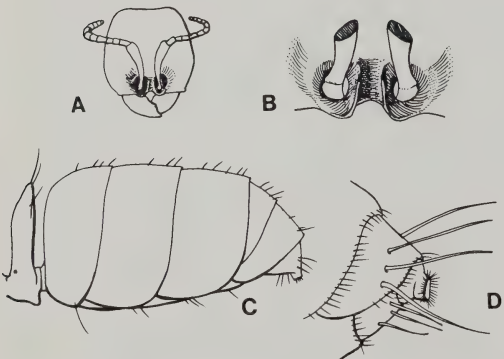

Fig. 6.—Diagnostic parts of worker ants. *A*, *Labidus*, front view of head; *B*, *Labidus*, enlarged view of bases of antennae; *C*, *Camponotus*, side view of petiole and gaster; *D*, *Camponotus*, nozzle-like anal opening at tip of abdomen.

delineating several sclerites, always including a large V-shaped or U-shaped scutellum (Fig. 3) ..... **females**

Wingless, lacking wing stubs (Fig. 2); dorsum of thorax without a scutellum and associated sclerites ..... **workers**

SYNOPTIC KEYS

The following keys include all of the genera known from Illinois and a few others that are known to occur not far from this state and may ultimately be found here. Because most of the Illinois ants have a wide distribution, this synopsis should be helpful for the entire Midwest. The only North American subfamily not represented in these keys is the southwestern subfamily Cerapachyinae.

This subfamily contains only two genera in North Ameri ca, *Cerapachys* and *Acanthostichus*, whose workers an queens may be distinguished by the spines on the latera margins of the terminal abdominal sternum.

The genera treated in this synopsis have been num bered serially. To facilitate referring from the keys t the generic synopses, the genera have been given th same numbers in the keys as in the following synopse

KEY TO SUBFAMILIES AND GENERA (WORKERS)

1. Petiole two segmented (Fig. 2 and 5) .....
   Petiole one segmented (Fig. 7*C*, *D*, and *E*) .....
2. Head with long, smooth eyes; antennae always clos together at base; scape little more than ha length of head (Fig. 5*B*); medium-sized to larg ants of wasplike appearance (Fig. 5*A*) (sul family **Pseudomyrmecinae**) 2
   Head shorter, eyes no larger than in Fig. 10; bas of antennae frequently well separated (Fig. 10 antenna usually with scape longer, frequent longer than head .....
3. Compound eye represented by only one facet or a sent (Fig. 6*A*); a pair of high, sharp ridg arising from head between antennal bases (Fi 6*B*) (subfamily **Ecitoninae**) .....
   Compound eye represented by more than a sing facet (Fig. 10); head without high ridges li those in Fig. 6*B* (subfamily **Myrmecinae**) ...
4. Genital opening small and circular, surrounded stiff hairs forming a terminal nozzle (Fig. 6*C* a *D*) (subfamily **Formicinae**) .....
   Genital opening slitlike or inconspicuous (Fig. 7) .
5. Gaster with a distinct constriction between first a second segments; abdomen with a well-develop sting (Fig. 7) (subfamily **Ponerinae**) .....
   Gaster without a constriction between first and s

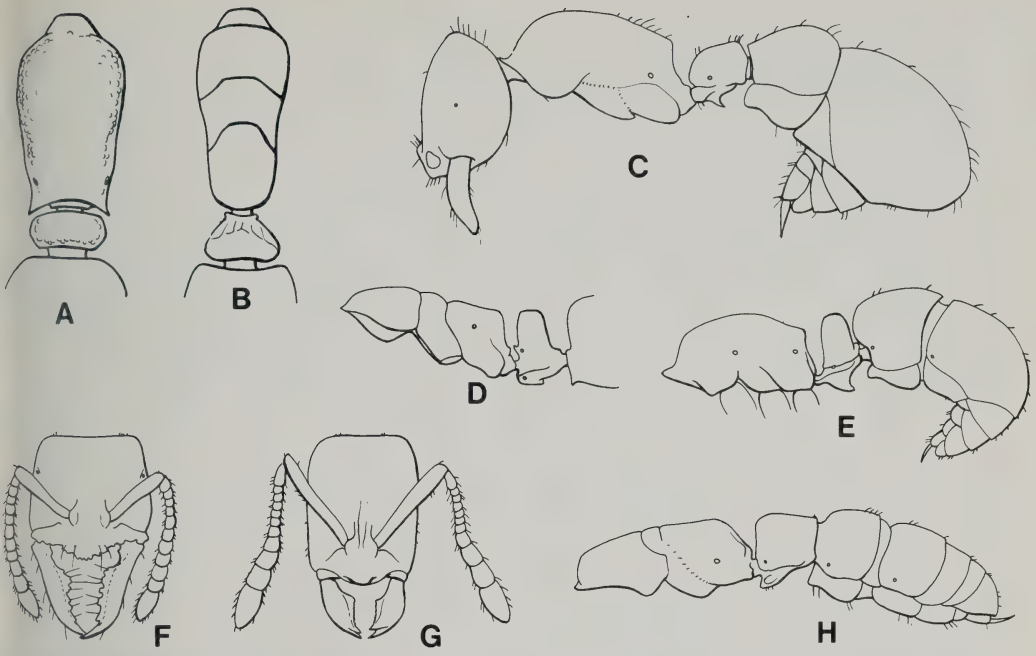

Fig. 7.—Diagnostic parts of worker ants of the subfamily Ponerinae. *A, Proceratium,* dorsal view of thorax; *B, Ponera,* dorsal iew of thorax; *C, Sysphincta,* side view of body; *D, Ponera,* side view of thorax and petiole; *E, Proceratium,* side view of thorax nd abdomen; *F, Amblyopone,* front view of head; *G, Ponera,* front view of head; *H, Amblyopone,* side view of thorax and abdo- ıen.

ond segments (Fig. 8) ; abdomen without a sting (subfamily **Dolichoderinae**) 10

ubfamily ECITONINAE

6. Tarsal claw toothed (Fig. 17*A*) ..... **1. Labidus**
Tarsal claw without a tooth (Fig. 17*B*) ..... **2. Neivamyrmex**

ubfamily PONERINAE

7. Thorax with no sutures visible in dorsal view (Fig. 7*A*) 8
Thorax with two sutures visible in dorsal view (Fig. 7*B*) 9

8. Terminal portion of abdomen arising near anterior end of ventral margin of end of second gastric segment; petiole moderately long and low in lateral view (Fig. 7*C*) ..... **6. Sysphincta**
Terminal portion of abdomen arising from near posterior end of second gastric segment; petiole high and short in lateral view (Fig. 7*E*) ..... **5. Proceratium**

9. Mandibles as long as head (Fig. 7*F*) ; petiole almost square in lateral view (Fig. 7*H*) ..... **3. Amblyopone**
Mandibles only about half length of head (Fig. 7*G*) ; petiole rectangular and high in lateral view (Fig. 7*D*) ..... **4. Ponera**

Subfamily DOLICHODERINAE

10. Epinotum with a flat, U-shaped dorsal projection extending posteriorly (Fig. 8*B* and *E*) ..... **7. Dolichoderus**
Epinotum with either a conical projection (Fig. 8*D*) or none (Fig. 8*C*) 11

11. Epinotum with a conical process (Fig. 8*D*) ; mandible with a prominent bladelike terminal tooth, maxillary palp with segment 3 as long as segments 4, 5, and 6 combined (Fig. 8*F*) ..... **8. Dorymyrmex**
No conical process on epinotum (Fig. 8*C*) ; mandible without a bladelike tooth, maxillary palp with segment 3 much shorter than segments 4–6 combined 12

12. Node of petiole vestigial (Fig. 8*A*) .. **10. Tapinoma**
Node of petiole as prominent as in Fig. 8*C* ..... **9. Iridomyrmex**

Subfamily FORMICINAE

13. Antenna with 9 segments .....**11. Brachymyrmex**
Antenna with 12 segments (Fig. 2) 14

14. Mandibles sickle shaped, their inner margins with a series of minute bumps or crenulations but no teeth (Fig. 9*A*) ..... **16. Polyergus**
Mandibles stouter and toothed (Fig. 14*B–D*) ...15

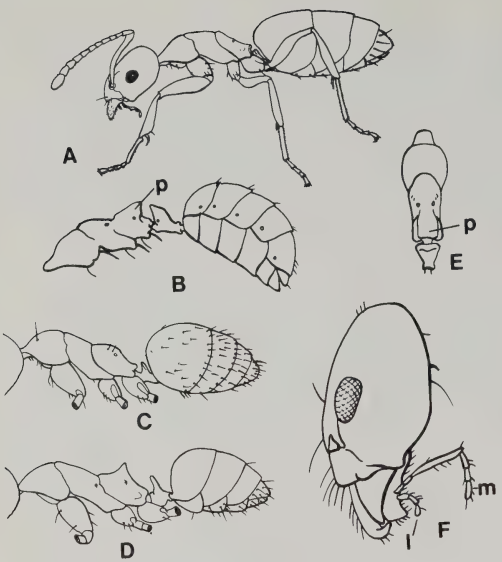

Fig. 8.—Diagnostic parts of worker ants of the subfamily Dolichoderinae. *A, Tapinoma,* side view; *B, Dolichoderus,* side view of thorax and abdomen—*p,* dorsal process; *C, Iridomyrmex,* side view of thorax and abdomen; *D, Dorymyrmex,* side view of thorax and abdomen; *E, Dolichoderus,* dorsal view of thorax and petioles—*p,* dorsal process; *F, Dorymyrmex,* side view of head—*l,* labial palp; *m,* maxillary palp.

15. Maxillary palp with three or four segments ..... **12. Acanthomyops**
Maxillary palp with five or six segments 16
16. Mesopleuron with a distinct ridge near anterior ventral portion (Fig. 9*B*) ..... **15. Camponotus**
Anterior margin of mesopleuron rounded, without ridge 17
17. Node of petiole low and sloping anteriorly, the whole petiole forming a low triangle (Fig. 9*D, E,* and *G*) 18
Node of petiole upright, petiole forming a high triangle (Fig. 9*C* and *F*) 19
18. Thorax viewed from the side having a distinct constriction or "neck" near middle (Fig. 9*G*) ..... **17. Prenolepis**
Thorax viewed from the side having no such distinct constriction or "neck" (Fig. 9*D* and *E*) ..... **18. Paratrechina**
19. Clypeus shorter, as in Fig. 14*C,* with an indistinct transverse swelling; dorsum of epinotum somewhat angulate (Fig. 9*F*) ..... **13. Lasius**
Clypeus longer, as in Fig. 14*D,* with a slight mesal crest or angulation for most of its length; dorsum of epinotum smoothly rounded (Fig. 9*C*) ..... **14. Formica**

Subfamily PSEUDOMYRMECINAE

20. Includes only one genus in North America (Fig. 5) ..... **19. Pseudomyrmex**

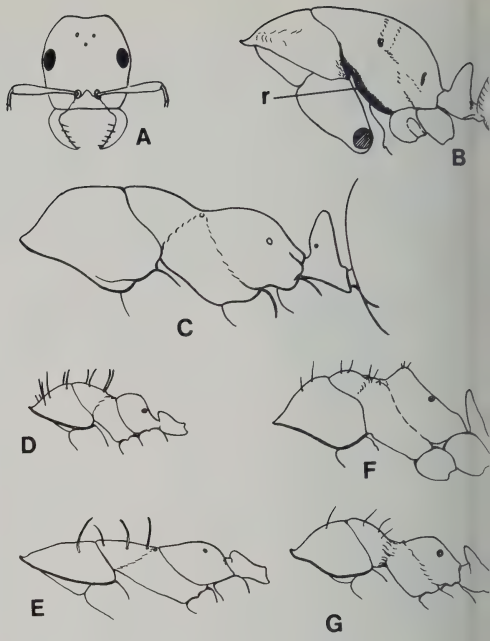

Fig. 9.—Diagnostic parts of worker ants of the subfam Formicinae. *A, Polyergus,* front view of head; *B, Camponot* side view of thorax and petiole—*r,* ridge; *C, Formica,* side vi of thorax and petiole; *D, Paratrechina,* side view of thor and petiole; *E, Paratrechina,* side view of thorax and petio *F, Lasius,* side view of thorax and petiole; *G, Prenolepis,* s view of thorax and petiole.

Subfamily MYRMECINAE

21. Pedicel attached to dorsal surface of gaster, which flattened dorsally and markedly heart shap (Fig. 25) ..... **26. Crematogas**
Pedicel attached near center of anterior end gaster, which is ovoid in shape (Fig. 2) .....
22. Dorsum of thorax with tubercles, as in Fig. 23*B* ..... **21. Trachymyrm**
Dorsum of thorax without tubercles .....
23. Front part of mesonotum with long spines project forward (Fig. 23*A*) ..... **20. A**
Front part of mesonotum without spines (Fig. 1 *D, G, H,* and *I*) .....
24. Head somewhat wedge shaped in full-face vi (Fig. 24) .....
Head not wedge shaped in full-face view (Fig. 1 and *F*) .....
25. Mandibles as long as in Fig. 24*A* and *B* ..... **22. Strumige**
Mandibles shorter, as in Fig. 24*C* and *D* ..... **23. Smithistru**
26. Epinotum with dorsal margin smoothly round without spines or angulation (Fig. 1*E*) .....
Epinotum with spines (Fig. 10*C, D, G,* and *H* with an angulate posterior dorsal margin (

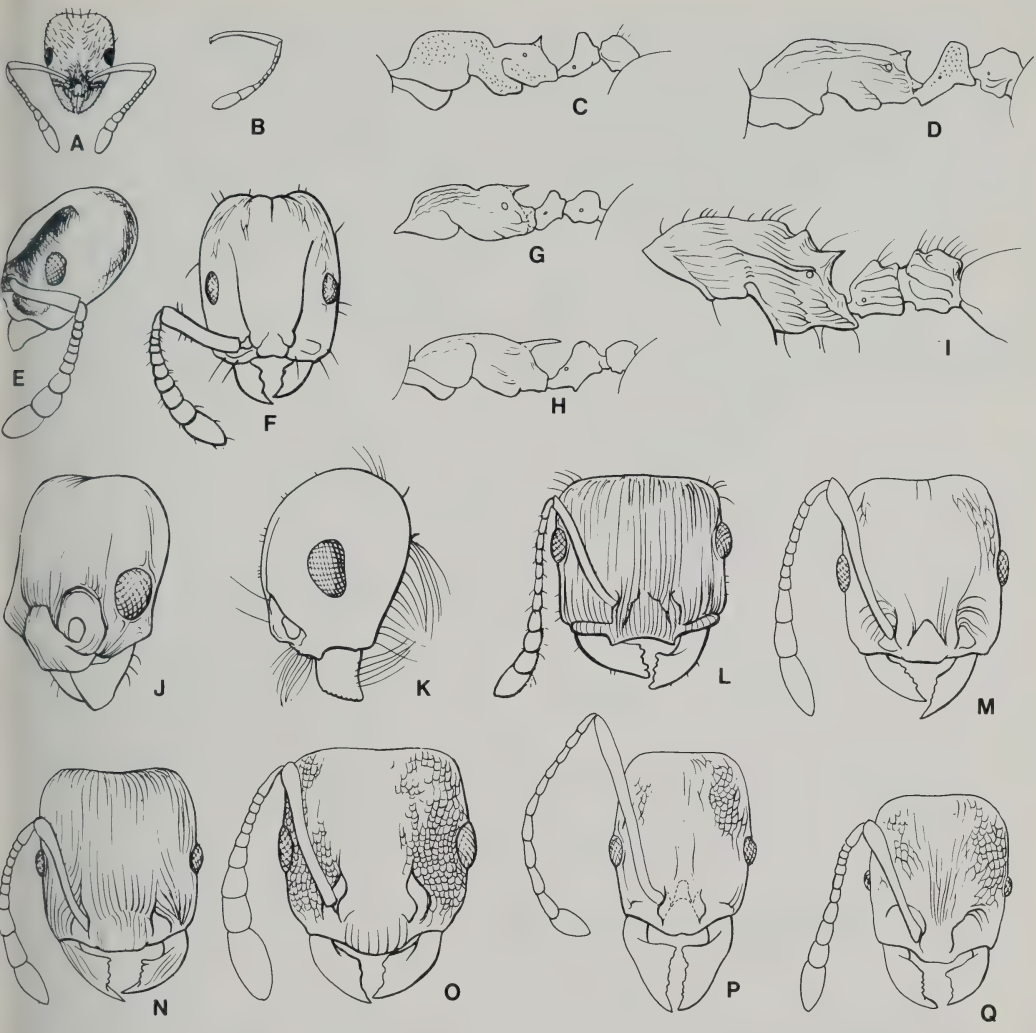

Fig. 10.—Diagnostic parts of worker ants of the subfamily Myrmecinae. *A, Monomorium,* front view of head; *B, Solenopsis,* tenna; *C, Pheidole,* side view of thorax and petiole; *D, Tetramorium,* side view of thorax and petiole; *E,* and *F, Harpagoxenus,* le and front views of head; *G, Myrmica,* side view of thorax and petiole; *H, Leptothorax,* side view of thorax and petiole; *I,* yrmecina, side view of thorax and petiole; *J, Myrmica,* tangential view of head; *K,* and *L, Pogonomyrmex,* side and front views head; *M, Pheidole,* front view of head; *N, Tetramorium,* front view of head; *O, Leptothorax,* front view of head; *P, Aphaeno-* ster, front view of head; *Q, Stenamma,* front view of head.

10*I*) 28

. Antenna with 10 segments, the last two forming a distinct club (Fig. 10*B*) ..... **27. Solenopsis**

Antenna with 12 segments, club either not distinctly set off or having three or more segments (Fig. 10*A*) ..... **28. Monomorium**

. Antennal scrobes well developed, extending beyond the posterior margin of the eye (Fig. 10*E* and *F*) 29

Antennal scrobes not reaching the posterior border of the eye (Fig. 10*J*–*Q*) 30

29. Minute yellow ants, at most 1.5 mm long ..... **24. Wasmannia**

Brown ants about 2.5 mm long.. **25. Harpagoxenus**

30. Posterior border of clypeus with a distinct, semicircular, deep, sharp depression (Fig. 10*J*); epinotum with a large lateral flange covering part of base of petiole (Fig. 10*G*). .**34. Myrmica**

Posterior border of clypeus with a short, shallow depression (Fig. 10*E*) or its margin merging

smoothly into the rest of the head (Fig. 10*K*); epinotum with a smaller or inconspicuous flange at base of petiole (Fig. 10*D*) 31

31. First segment of petiole slightly shorter than second; epinotum with an almost spinelike flange above each posterior spine (Fig. 10*I*) .. **31. Myrmecina**

First segment of petiole longer than second, its anterior portion narrow; epinotum usually without spinelike flange above each posterior spine (Fig. 10*C, D, G,* and *H*) 32

Fig. 11.—*Pseudomyrmex* queen, front view of head.

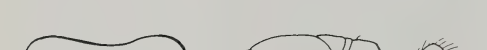

Fig. 12.—Diagnostic parts of queen ants of the subfamily Ponerinae. *A, Amblyopone,* front view of head; *B, Ponera,* side view of thorax and petiole; *C, Amblyopone,* side view of thorax and petiole.

32. Mesal portion of anterior margin of clypeus concave (Fig. 10*L*); ventral side of head with long curved hairs (Fig. 10*K*) ... **29. Pogonomyrmex**

Mesal portion of anterior margin of clypeus produced, convex, or bilobed (Fig. 10*M–Q*); ventral side of head without such long curved hairs 33

33. Dorsal profile of thorax forming an even (Fig. 10*H*) or only slightly indented arc (Fig. 10*D*) 34

Dorsal profile of thorax markedly steplike or sinuate (Fig. 10*C*) 35

34. Head with straight and strong striae over its entire front and dorsal surface (Fig. 10*N*); dark brown ants ..... **35. Tetramorium**

Head covered with weak striae, many connected with cross-striae to give a reticulate appearance (Fig. 10*O*); light brown ants, usually with a pair of dark brown suffusions on the abdomen ..... **36. Leptothorax**

35. Second antennal segment not much longer than third segment; scape extending far above dorsal margin of head (Fig. 10*P*) .. **30. Aphaenogaster**

Second antennal segment as long as next two or three combined; scape not as long (Fig. 10*L* and *Q*) 36

36. Eyes as large as in Fig. 10*M* and last three antennal segments enlarged into a club; two types of workers, one with a greatly enlarged head ..... **33. Pheidole**

Eyes smaller and antennal club not pronounced (Fig. 10*Q*); only one type of worker, with ordinary-sized head ..... **32. Stenamma**

KEY TO SUBFAMILIES AND GENERA (QUEENS)

1. Petiole two segmented (Fig. 3) .....

Petiole one segmented (Fig. 12*B*) .....

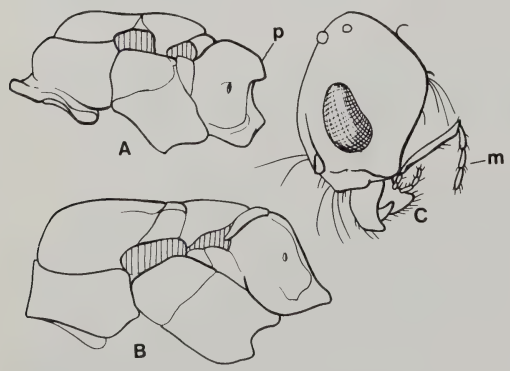

Fig. 13.—Diagnostic parts of queen ants of the subfamily Dolichoderinae. *A, Dolichoderus,* side view of thorax and propodeum—*p,* posterior projection of epinotum; *B, Tapinoma,* side view of thorax and epinotum; *C, Dorymyrmex,* side view of head—*m,* maxillary palp.

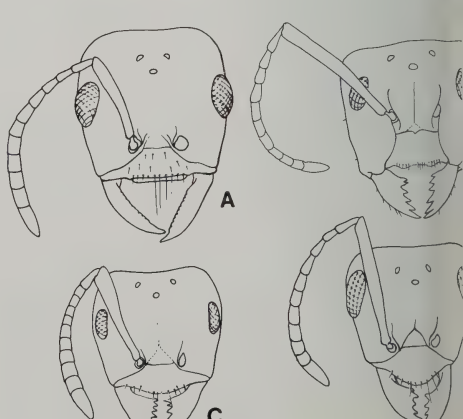

Fig. 14.—Front views of heads of queen ants of the subfamily Formicinae. *A, Polyergus; B, Camponotus; C, Lasius; Formica.*

2. Compound eye represented by only one facet or absent (subfamily **Ecitoninae**) 6
Compound eye represented by more than a single facet (Fig. 12*A*) 3
3. Head oblong in face view, with large, smooth eyes (Fig. 11); antennae always close together at base, scape little more than half length of head (Fig. 11); medium-sized to large ants of wasp-like appearance (subfamily **Pseudomyrmecinae**) 20
Head shorter, eyes no larger than in Fig. 13; bases of antennae frequently well separated; scape usually longer, frequently longer than head (Fig. 3) (subfamily **Myrmecinae**) 21
4. Genital opening small and circular, surrounded by stiff hairs forming a terminal nozzle (Fig. 6*C* and *D*) (subfamily **Formicinae**) 13
Genital opening slitlike or inconspicuous (Fig. 7*C*) 5
5. Gaster with a distinct constriction between first and second segments; abdomen with a well-developed sting that is frequently retracted and not visible externally (Fig. 7*C*) (subfamily **Ponerinae**) 7
Gaster without a constriction between first and second segments (Fig. 8*A–D*); abdomen without a sting (subfamily **Dolichoderinae**) 10

Subfamily ECITONINAE

6. Tarsal claw toothed (Fig. 17*A*) ..... **1. Labidus**
Tarsal claw without a tooth (Fig. 17*B*) ..... **2. Neivamyrmex**

Subfamily PONERINAE

7. Scale of petiole upright, rectangular (Fig. 12*B*) .. 8
Scale of petiole ovoid, rounded (Fig. 12*C*) 9
8. Second segment of abdomen unusually large (Fig. 7*E*) ..... **5. Proceratium**
Second segment of abdomen of normal size (Fig. 7*H*) ..... **4. Ponera**
9. Mandibles with enlarged teeth (Fig. 12*A*); second segment of abdomen of normal size (Fig. 7*H*) ..... **3. Amblyopone**
Mandibles without enlarged teeth; second segment of abdomen unusually large (Fig. 7*C*) ..... **6. Sysphincta**

Subfamily DOLICHODERINAE

10. Epinotum with a flat, dorsal projection extending posteriorly and forming an overhang in lateral view (Fig. 13*A*) ..... **7. Dolichoderus**
Epinotum without a dorsal projection (Fig. 13*B*) 11
11. Maxillary palp with segment 3 as long as segments 4, 5, and 6 combined (Fig. 13*C*) ..... **8. Dorymyrmex**
Maxillary palp with segment 3 much shorter than segments 4–6 combined 12
12. Node of petiole vestigial (Fig. 8*A*) .. **10. Tapinoma**
Node of petiole as prominent as in Fig. 8*C* ..... **9. Iridomyrmex**

Subfamily FORMICINAE

13. Antenna with 9 segments ..... **11. Brachymyrmex**
Antenna with 12 segments 14
14. Mandibles sickle shaped, their inner margins with minute indentations but no teeth (Fig. 14*A*) ..... **16. Polyergus**
Mandibles stouter and toothed (Fig. 14*B*) 15
15. Maxillary palp with three or four segments ..... **12. Acanthomyops**
Maxillary palp with five or six segments 16

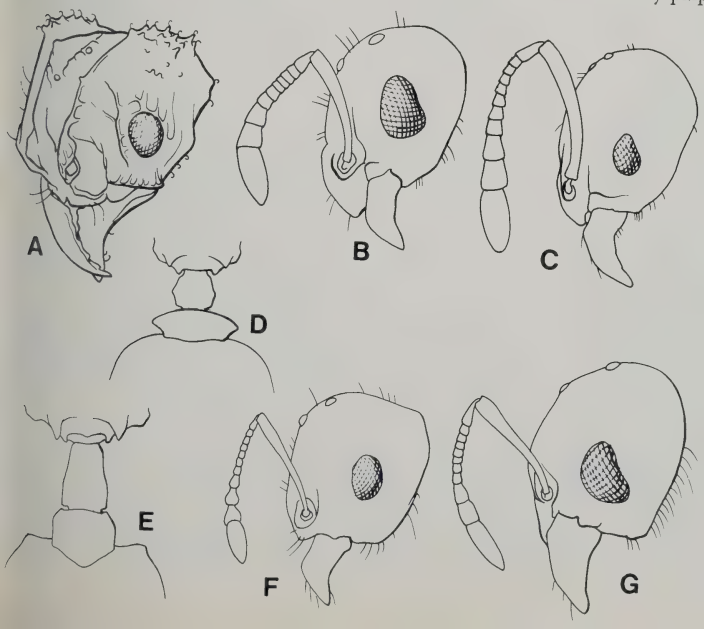

Fig. 15. — Diagnostic parts of queen ants of the subfamily Myrmecinae. *A, Trachymyrmex,* tangential view of head; *B, Leptothorax,* side view of head; *C, Stenamma,* side view of head; *D, Pheidole,* dorsal view of petiole; *E, Leptothorax,* dorsal view of petiole; *F, Tetramorium,* side view of head; *G, Pheidole,* side view of head.

16. Antennal sockets some distance from posterior margin of clypeus (Fig. 14*B*); clypeus somewhat rectangular, with part of its lateral margins nearly parallel ..... **15. Camponotus**

Antennal sockets close to or touching posterior margin of clypeus (Fig. 14*C* and *D*); clypeus almost diamond shaped, its lateral margins very oblique 17

17. Node of petiole low and sloping anteriorly, the whole petiole forming a low triangle (Fig. 9*E* and *G*) 18

Node of petiole upright, the entire petiole forming a high triangle (Fig. 9*C* and *F*) 19

18. Scapes of antennae extending beyond the upper margin of the head by about one-third their length or more ..... **18. Paratrechina**

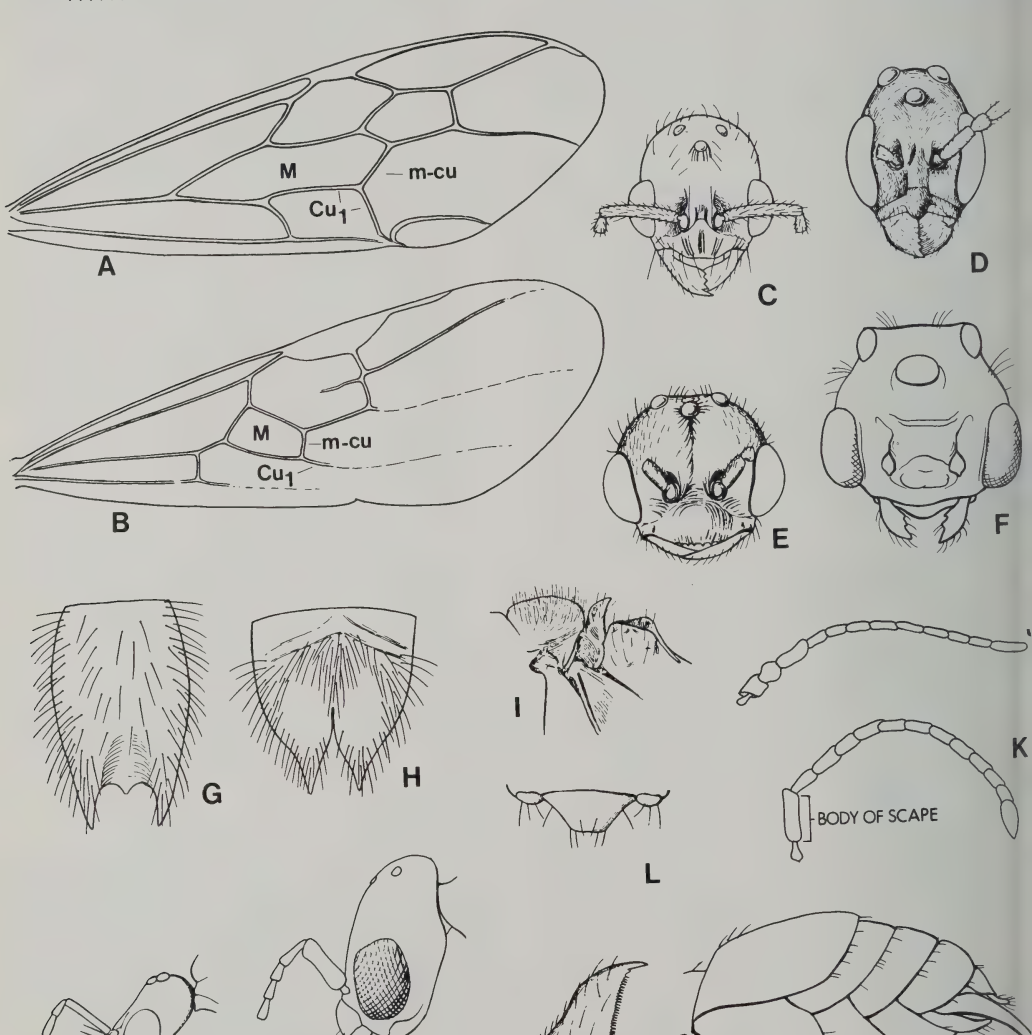

Fig. 16.—Diagnostic parts of male ants. *A, Labidus,* front wing; *B, Myrmica,* front wing; *C, Stenamma,* front view of he *D, Pseudomyrmex,* front view of head; *E, Amblyopone,* front view of head; *F, Pheidole,* front view of head; *G, Neivamyrmex,* ven view of subgenital plate; *H, Labidus,* ventral view of subgenital plate; *I, Proceratium,* lateral view of petiole and base of gaster *Solenopsis,* antenna; *K, Dolichoderus,* antenna; *L, Myrmecina,* front view of mandibles and labrum; *M, Aphaenogaster,* side vie head of small specimen; *N, Aphaenogaster,* side view of head of robust specimen; *O, Tapinoma,* front view of mandible; *P, W mannia,* side view of abdomen. (All except *F, J, K,* and *N* after M. R. Smith, courtesy of the *American Midland Natural*

Scapes of antennae extending beyond the upper margin of the head less than one-third their length; scale of petiole with a broad median impression ..... **17. Prenolepis**

19. Clypeus longer, as in Fig. 14*D*, with a slight mesal crest or angulation for most of its length ..... **14. Formica**

Clypeus shorter, as in Fig. 14*C*, without a mesal crest but with an indistinct transverse swelling ..... **13. Lasius**

Subfamily PSEUDOMYRMECINAE

20. Includes only one genus in North America ..... **19. Pseudomyrmex**

Subfamily MYRMECINAE

21. Head with dorsolateral projections (Fig. 23) ...22
Head without dorsolateral projections (Fig. 15*B*) 23

22. Head with long scrobe and several small tubercles (Fig. 15*A* and 23*B*) ..... **21. Trachymyrmex**
Head with short scrobe and no tubercles (Fig. 23*A*) ..... **20. Atta**

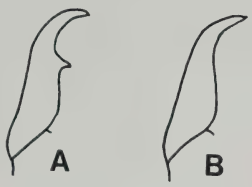

Fig. 17.—Tarsal claws of army ants. *A, Labidus; B, Neivamyrmex.* (After M. R. Smith, courtesy of *American Midland Naturalist*)

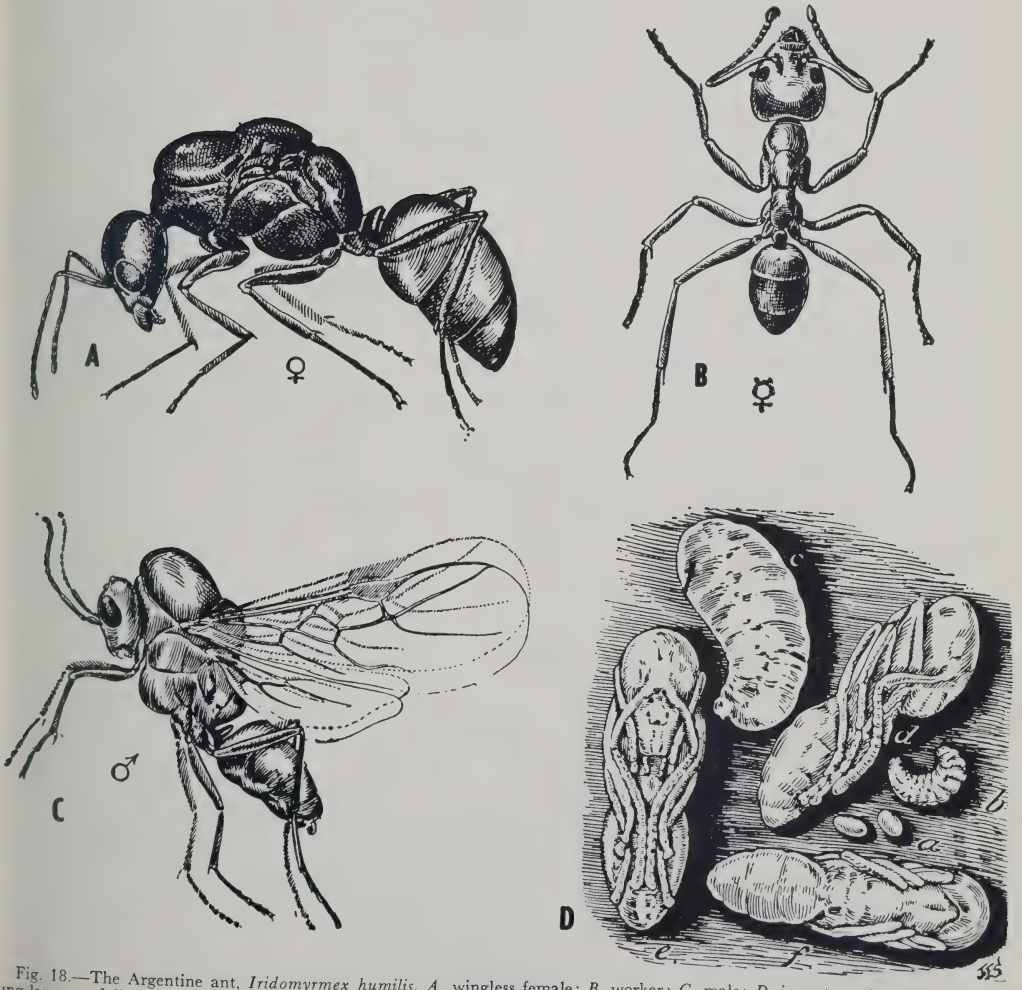

Fig. 18.—The Argentine ant, *Iridomyrmex humilis. A,* wingless female; *B,* worker; *C,* male; *D,* immature stages: *a,* eggs; *b,* ung larva; *c,* full-grown larva; *d,* pupa, side view; *e,* pupa, ventral view; *f,* pupa, dorsal view. All about 12 times natural size.

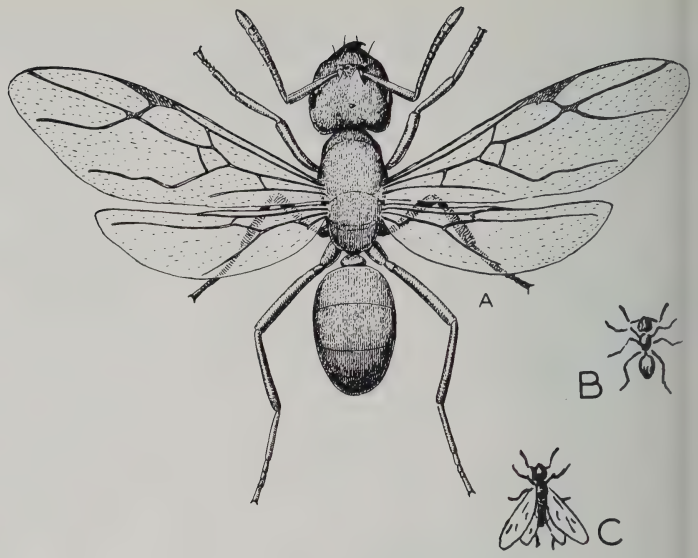

Fig. 19.—A common foundation ant, *Acanthomyops interjectus*. *A*, winged queen; *B*, worker; *C*, winged queen. *B* and *C*, natural size. (From Illinois Natural History Survey Circular 39)

23. Head somewhat heart shaped, as in Fig. 24 24
    Head not heart shaped 25
24. Mandibles longer, as in Fig. 24*A* and *B* ..... **22. Strumigenys**
    Mandibles shorter, as in Fig. 24*C* and *D* ..... **23. Smithistruma**
25. Antennal scrobe extending to or beyond the posterior margin of the eye (Fig. 10*E* and *F*) . . .26
    Antennal scrobe not reaching the posterior margin of the eye 27
26. Yellow-orange ants with many deep longitudinal rugae on the head ..... **24. Wasmannia**
    Brown ants with head dull but not markedly rugose ..... **25. Harpagoxenus**
27. Epinotum without spines 28
    Epinotum with spines (Fig. 3) 29
28. Antenna with a distinct two-segmented club (Fig. 10*B*) ..... **27. Solenopsis**
    Antenna without a two-segmented club (Fig. 10*A*) ..... **28. Monomorium**
29. First segment of petiole either shorter than second or without a dorsal projection (Fig. 10*I*) 30
    First segment of petiole longer than second and with a marked dorsal hump on its posterior half (Fig. 10*C, D, G,* and *H*).....31
30. Head with strong longitudinal rugae, much as in Fig. 10, texture somewhat dull . .**31. Myrmecina**
    Head with only faint sculpturing, surface shiny ..... **26. Crematogaster**
31. Mesal portion of anterior margin of clypeus concave (Fig. 10*L*); ventral side of head with long curved hairs (Fig. 10*K*) ... **29. Pogonomyrmex**
    Mesal portion of anterior margin of clypeus either produced, convex, or bilobed (Fig. 10*M–Q*); ventral side of head without such long curved hairs 3
32. Posterior border of clypeus with a distinct semicir cular, deep, sharp depression (Fig. 10*J*); epino tum with large flange at base of petiole (Fig 10*G*) ..... **34. Myrmic**
    Posterior border of clypeus with either a short, sha low depression (Fig. 10*M*), or its margin merg ing smoothly into rest of head (Fig. 10*N*) epinotum with smaller or inconspicuous flange base of petiole (Fig. 10*C*) .....
33. Pedicel extending far above dorsal margin of hea (Fig. 10*P*) ..... **30. Aphaenogast**
    Pedicel not extending above dorsal margin of hea (Fig. 10*O*) .....
34. Dorsal aspect of second segment of petiole about wide as long, its sides nearly straight (F 15*E*) .....
    Dorsal aspect of second segment of petiole abo twice as wide as long, its sides angulate (F 15*D*) .....
35. Eyes as large as in Fig. 15*B* ..... **36. Leptothor**
    Eyes smaller, as in Fig. 15*C* ..... **32. Stenamm**
36. In lateral view, long axis of eye nearly parallel long axis of head (Fig. 15*F*) . . **35. Tetramoriu**
    In lateral view, long axis of eye markedly tangent to long axis of head (Fig. 15*G*) ... **33. Pheid**

KEY TO SUBFAMILIES AND GENERA (MALES)

1. Petiole of two segments .....
   Petiole of only one segment .....
2. Eyes elongate and bean shaped; clypeus not exte ing close to bases of antennae (Fig. 16*D*) (s family **Pseudomyrmecinae**) .....
   Eyes relatively small, ovoid, or hemiovoid (Fig. 2

and *H*) ; clypeus extending dorsally almost to or above level of antennal bases (subfamily **Myrmecinae**) 23

3. Subgenital plate elongate, with two or three apical teeth (Fig. 16*C, E,* and *F*) ; front wing with cell M long, vein Cu_1 with a sharp bend at crossvein *m-cu,* and Cu_{1a} distinct and sclerotized (Fig. 16*A*) (subfamily **Ecitoninae**) 5
Subgenital plate without apical teeth; front wing, if present, with cell M much shorter or open, vein Cu_1 with only a slight curve or none at crossvein *m-cu,* which is sometimes atrophied, and Cu_{1a} usually forming only an indistinct apex to Cu_1 (Fig. 16*B*) 4
4. A pronounced constriction between first and second gastric segments (Fig. 7*C, E,* and *H*) (subfamily **Ponerinae**) 6
No constriction between first and second gastric segments (Fig. 8*A* and *B*; Fig. 9*B*) (subfamilies **Dolichoderinae** and **Formicinae**) 10

Subfamily ECITONINAE

5. Tarsal claws with a tooth (Fig. 17*A*) .. **1. Labidus**
Tarsal claws simple (Fig. 17*B*) .. **2. Neivamyrmex**

Subfamily PONERINAE

6. Wingless ..... **4. Ponera**
Winged 7
7. Metanotum with a dorsal spine (Fig. 16*I*) 8
Metanotum without a spine 9
8. Petiole rectangular or angulate at apex in lateral view ..... **5. Proceratium**
Petiole rounded at apex in lateral view ..... **6. Sysphincta**
9. Clypeus with minute teeth (Fig. 16*E*) ..... **3. Amblyopone**
Clypeus without teeth (Fig. 16*F*) ..... **4. Ponera**

Subfamilies DOLICHODERINAE and FORMICINAE

10. Antenna 10-segmented; pale cream colored ants ..... **11. Brachymyrmex**
Antenna with 13 segments 11
11. Second segment of funicle longer than body of scape (Fig. 16*P*) ..... **9. Iridomyrmex**
Second segment of funicle about the same length as or shorter than body of scape 12
12. Third segment of maxillary palp as long as segments 4, 5, and 6 combined ..... **8. Dorymyrmex**
Third segment of maxillary palp much shorter than segments 4, 5, and 6 combined 13
13. Maxillary palp three or four segmented ..... **12. Acanthomyops**
Maxillary palp five or six segmented 14
14. Body of scape shorter than the combined lengths of the first three funicular segments (Fig. 16*K*) ..... **7. Dolichoderus**
Body of scape as long as or longer than the combined lengths of the first three funicular segments 15
15. Mandible sickle shaped, without distinct teeth (Fig. 14*A*) ..... **16. Polyergus**
Mandible somewhat triangular, sometimes with teeth 16
16. Anterior face of the gaster flat or convex 17
Anterior face of the gaster dished out and concave, forming a shallow cavity into which the petiole fits in repose 19
17. Body of scape shorter than combined lengths of first four funicular segments; body length 2–3 mm ..... **9. Iridomyrmex**
Body of scape much longer than combined lengths of first four funicular segments; body length 5–10 mm 18
18. Antennae inserted at a distance from the posterior margin of the clypeus ..... **15. Camponotus**
Antennae inserted close to the posterior margin of the clypeus ..... **14. Formica**
19. Body of scape shorter than the first four funicular segments combined ..... **17. Prenolepis**
Body of scape longer than the first four funicular segments combined 20
20. Petiole upright and high ..... **13. Lasius**
Petiole inclined forward and lower 21
21. Mandible with many microscopic teeth (Fig. 16*O*) ..... **10. Tapinoma**
Mandible with larger and fewer teeth (Fig. 16*C*) ..... **18. Paratrechina**

Subfamily PSEUDOMYRMECINAE

22. Only one genus ..... **19. Pseudomyrmex**

Subfamily MYRMECINAE

23. Antenna 10 segmented ..... **35. Tetramorium**
Antenna with more than 10 segments 24
24. Head and body with many erect long hairs (Fig.

Fig. 20.—Winged female of the large black carpenter ant, *Camponotus pennsylvanicus.* (From USDA)

10*K*) ; clypeus shallow, its apical margin concave (Fig. 10*L*) ..... **29. Pogonomyrmex**

Head and body with a few erect hairs, but these are never long or numerous; clypeus deeper and somewhat convex (Fig. 10*M*) 25

25. Antenna 11 or 12 segmented 26
Antenna 13 segmented 29

26. Petiole attached high on anterior face of gaster; segments of funicle appearing somewhat beadlike ..... **26. Crematogaster**

Petiole attached low on anterior face of gaster; segments of funicle not at all beadlike 27

27. First funicular segment enlarged, often globose, scape very short (Fig. 16*J*) ..... **27. Solenopsis**

First funicular segment not markedly enlarged, scape longer, as in Fig. 16*K* 28

28. Antennal scrobes well developed (Fig. 10*E*) ..... **25. Harpagoxenus**

Antennal scrobes weakly developed or absent ..... **36. Leptothorax**

29. Mandibles vestigial, reduced to short fleshy stubs (Fig. 16*L*) ..... **31. Myrmecina**

Mandibles developed and sclerotized, although sometimes small 30

30. Abdomen in lateral view with a pair of elongate processes (the parameres of the genitalia) protruding from the posterior tip (Fig. 16*P*) ..... **24. Wasmannia**

Abdomen with only short protruding processes, which are blunt at the tip, or no visible protruding structures 31

31. Scape very long, at least as long as the first eight funicular segments combined 32

Scape shorter, not as long as the first eight funicular segments 33

32. Front wing with cell R_1 short and wide (Fig. 22*B*) ..... **21. Trachymyrmex**

Front wing with cell R_1 long and narrow (Fig. 22*A*) ..... **20. Atta**

33. Stigma of forewing weakly developed or missing (males too poorly known to permit further identification without other castes).. **22. Strumigenys** **23. Smithistruma**

Stigma of forewing well developed, as in Fig. 16*B*, but sometimes pale 34

34. Head flattened and either shallowly elliptic (Fig. 16*M*) or almost rectangular in lateral view (Fig. 16*N*) ..... **30. Aphaenogaster**

Head much more rounded 35

35. Base of clypeus ending in a marked semicircular depression (Fig. 10*J*) ..... **34. Myrmica**

Base of clypeus ending in a shallow triangular impression, or no depression evident 36

36. Body of scape very short, at most as long as the first and second funicular segments combined 37

Body of scape longer than the first and second funicular segments combined 38

37. Funicle threadlike, the same thickness for its entire length; ocelli on a high protuberance (Fig. 16*F*) ..... **33. Pheidole**

Funicle with last four segments much thicker than first few segments; ocelli not on a protuberance ..... **28. Monomorium**

38. Ocelli small, separated from each other by twice the diameter of one of them (Fig. 16*C*) ; epinotum concave in lateral view ..... **32. Stenamma**

Ocelli large, separated from each other by only the diameter of one of them, somewhat as in Fig. 16*E*; epinotum convex in lateral view ..... **36. Leptothorax**

SYNOPSES OF GENERA

Subfamily ECITONINAE

These ants are the native American army ants, differing in many characters from the army ants of the Old World. The New World species occur chiefly in the tropics, where the workers may form long foraging columns. Their food is mostly other insects and small ground-dwelling animals, but they may kill fairly large animals. The nest is a temporary bivouac built around the queen and brood. Only two genera occur in or near Illinois.

1. Labidus Jurine

No species have been recorded from Illinois, but *L. coecum* (Latreille) is known from Louisiana, Oklahoma and Texas and may eventually be found in Illinois. The workers range from 3 to 10 mm long, the larger ones with slightly enlarged heads.

2. Neivamyrmex Borgmeier

The southern and southwestern species, *N. nigrescens* (Cresson), has been found sporadically in extreme south

Fig. 21.—Worker of the crazy ant, *Prenolepis longicornis*. (After Wheeler)

ern Illinois, where it may be an occasional pest in swimming pools and basements. In this species the workers are 3–6 mm long and dark blackish red, the larger ones with slightly swollen heads. Several other species occur to the south and west of Illinois.

Subfamily PONERINAE

The ants comprising this subfamily are seldom found without a deliberate search of rotten logs or beneath leaves and stones on the forest floor. They both forage for small prey and nest in these situations. The nests are small, rarely containing more than 50 workers, and each nest may contain several queens. The workers and queens are reddish or reddish brown, range from 2 to 6 mm in length, and have a sting.

Of the 12 or more genera known from North America, the 4 more northern ones have been taken in Illinois. None of the Illinois species is economic. Only rarely are any of them found in the garden or home.

3. Amblyopone Erichson

The sole Illinois species, *A. pallipes* Haldeman, (formerly placed in the genus *Stigmatomma* Roger) is the only one known from North America. It is readily recognized in the worker and queen castes by the elongate mandibles (Fig. 7*F*). Although widely distributed in Illinois, it is a rare species.

4. Ponera Latreille

This is the commonest ponerine ant genus in Illinois, where two of the seven North American species occur. The genus is unusual because some colonies produce wingless, workerlike males.

5. Proceratium Roger

Of the three North American species, only *P. croceum* Roger has been found in Illinois. It is a rare species whose nests are usually found in wood attacked by red rot.

6. Sysphincta Roger

Of the two North American species, only the widespread *S. pergandei* Emery has been found in Illinois. It is moderately rare.

Subfamily DOLICHODERINAE

These ants have no sting and the workers are all alike, with no larger soldier caste. Four of the six North American genera occur in Illinois; all of them are small, brownish or blackish ants, the workers ranging from 2.0 to 4.5 mm. Colonies usually contain several hundred individuals. All Illinois species forage in files.

7. Dolichoderus Lund

Two of the four U.S. species occur in Illinois. Their nest, made in the soil, is not craterlike and has a concealed opening. They are not economic and are seldom seen outside woodlands or forest edges. *Dolichoderus* is often found tending aphids.

8. Dorymyrmex Mayr

The sole North American species, *D. pyramicus*, has so far been collected in Illinois only in undisturbed sandy areas. The nest is usually in the open and craterlike, but occasionally is constructed under stones.

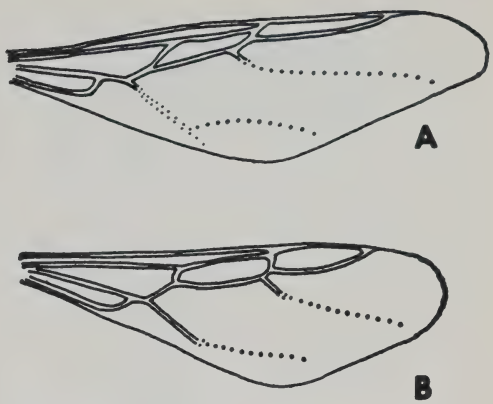

Fig. 22.—Wings of leaf-cutting ants. *A, Atta sexdens* Linnaeus; *B, Trachymyrmex cornetzi* Forel. (After Weber, courtesy of *Science*)

9. Iridomyrmex Mayr

Two species occur in Illinois, the introduced species, *I. humilis* (Mayr), (the Argentine ant) (Fig. 18) and the native *I. pruinosus* (Roger). In both, the workers are small, ranging from 2 to 3 mm long. Both species nest in soil or under stones or boards. The workers forage in narrow columns, often tend aphids, and eat a wide variety of vegetable and animal foods.

The Argentine ant is a domestic pest, entering houses and eating all types of sweets, meats, and vegetables. When crushed, the ants have a stale, greasy or musty odor.

Key to Species of Iridomyrmex Workers

Scape extending beyond top of head by only half the length of first funicular segment. Seldom in houses ..... **pruinosus**

Scape extending beyond top of head by the full length of first funicular segment. Frequently in houses ..... **humilis**

10. Tapinoma Foerster

Only the native species, *T. sessile* (Say), occurs in Illinois. It is a small ant, the worker ranging from 2.0 to 3.5 mm, and it is dark blackish brown. It nests in a great variety of sheltered places inside the house and outdoors, often with several thousand workers in a single nest. The species is practically omnivorous. Common in dwellings, it will eat almost any human food and contaminates foods with "Tapinoma odor," a smell somewhat like butyric acid that has earned this species the name of odorous house ant.

Subfamily FORMICINAE

Ants of this subfamily range from nearly the smallest to the largest of Illinois ants. The queens and workers have no sting but are characterized by the curious circle of hairs around the anal opening.

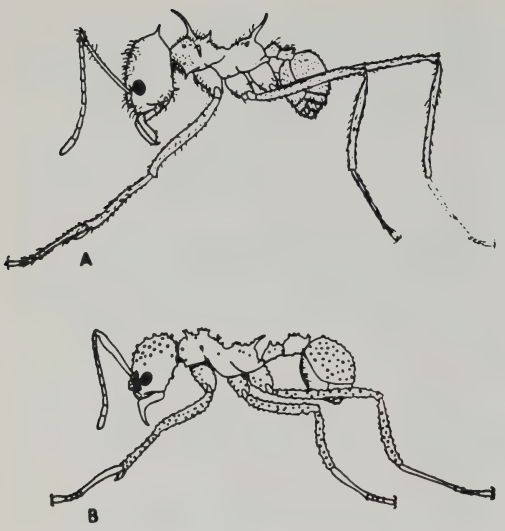

Fig. 23.—Workers of leaf-cutting ants. *A, Atta cephalotes* Linnaeus; *B, Trachymyrmex arizonensis* Wheeler. (After Weber, courtesy of *Science*)

11. **Brachymyrmex** Mayr

The sole U.S. and Illinois species, *B. depilis* Emery, has minute workers 1.5–2.0 mm long that forage in the leaf litter of woods and meadows. These ants nest under stones or in the soil and are seldom seen without deliberate search.

12. **Acanthomyops** Mayr

Of the nine U.S. species, only three are recorded from Illinois. The workers are 3.0–4.5 mm long and a medium shade of reddish brown. Normally these ants forage in leaf litter or underground, where they tend aphids and mealybugs, and are seldom seen except by a person digging in the garden. During the winter, however, entire colonies (including both workers and winged forms) frequently move to house foundations. If there is a break in the foundation, a colony of both workers and winged forms (Fig. 19) may move into the basement and take up residence under a loose brick or board. They do not raid through the house, but many persons find their company disconcerting. If the colony is disturbed, the ants emit a strong, citronellalike odor. When soil temperatures rise in spring, the ants will depart along the path by which they entered. This winter habit has earned them the name of foundation ants. Formerly these ants were classified in the genus *Lasius*.

13. **Lasius** Fabricius

The seven Illinois species, all native, are among its commonest field and garden ants. In most of them the workers are dark brown, ranging in size from 2 to 4 mm. They actively search for food above ground and may enter houses and eat a variety of sweats and meats. They make large nests in soil or under covering objects, each nest containing up to 10,000 workers.

Two cornfield ants, *L. alienus* Foerster and *L. neoniger* Emery, are often found tending aphids on corn and other plants. *L. neoniger* is known to spread the virus causing barley yellow dwarf by its aphid-tending activities.

14. **Formica** Linnaeus

The dozen Illinois species of this genus, all natives, are the most commonly observed of our entire ant fauna. The workers are brownish black, sometimes with the head red, and range in length from 2.5 to 6.0 mm. They forage actively, often in the open, and are called sidewalk ants.

These ants nest in soil. Some species construct a nest entirely below the soil surface with an obscure entrance. Others build large mounds over the nest, and each may contain 100,000 workers. They are scavengers, predators on other insects, and nectar feeders. In Illinois they enter houses only sporadically and singly, and hence are of no economic importance. If one disturbs them in the wild, however, they bite readily and inflict a painful wound.

Some species are "cuckoo" ants; that is, a young queen uses a colony of another species to start her own colony, first killing off the queen of the host species. This results in temporary colonies of mixed workers.

15. **Camponotus** Mayr

The ants of this genus are the carpenter ants (Fig. 20). Eight native species occur in Illinois, including our largest ants. Depending on the species, the workers may be all black, reddish brown, or tan and range in length from 3 to 13 mm in the same nest. The large workers have heads disproportionately larger than those of smaller individuals; these large, big-headed workers are called *majors,* the small ones *minors.* They tend aphids, forage in columns, and are general scavengers.

Most species of *Camponotus* nest in dead wood. In the wild they use logs, stumps, and the wood of standing dead trees. They also nest in timbers of houses, railings and poles, excavating tunnels by chewing out the soft wood between the harder annual rings of beams, siding and other structures, weakening the wood and frequently causing extensive damage. The species most frequently encountered in buildings is *C. pennsylvanicus* DeGeer, a large black species with long grayish or yellowish hairs on its upper surface.

16. **Polyergus** Latreille

These ants are the slave-making ants. Two native species occur in Illinois; the workers of both are reddish brown and 6–8 mm long. The nest is 100–120 cm deep in the soil and has an obscure opening. The workers are out of the nest only when scouting or raiding; they do no foraging.

On a raid the *Polyergus* workers attack a *Formica* nest and carry pupae of *Formica* workers back to the *Polyergus* nest. When these pupae develop and emerge

as adult workers, they adopt their new "household" and do the foraging for the entire nest. A *Polyergus* nest, therefore, contains the *Formica* "slave" workers that come and go freely and the *Polyergus* workers that spend most of their time inside the nest.

17. **Prenolepis** Mayr

The single native North American species, *P. imparis* (Say), occurs commonly throughout Illinois. The workers are dark brown and 2–4 mm in length. These aphid tenders and general scavengers forage in thin columns and build their inconspicuous nests in the ground. They are frequent pests in houses and greenhouses, eating a variety of domestic foods and sometimes gnawing the tips of flower buds and the shoots of plants for their juices. They take honey from weakened beehives.

18. **Paratrechina** Mutschoulsky

The genus is represented in Illinois by three species, including two native species resembling *Prenolepis imparis* in general appearance and an introduced species, *Paratrechina longicornis*. This latter is also small and dark but has very long, slender legs and a peculiar rolling gait when running, earning the species the common name of crazy ant (Fig. 21).

All of these species nest in the ground and may be general nuisances in the house, eating a variety of foods.

Subfamily PSEUDOMYRMECINAE

19. **Pseudomyrmex** Lund

The five or six native American species occur south of Illinois chiefly in the Gulf states and into the tropics. The workers are 4–10 mm in length, mostly yellow or brown, and wasplike in appearance. Some nest in hollow thorns on acacia trees; if the tree is disturbed, the workers dash out and inflict painful bites and stings.

Subfamily MYRMECINAE

This is a large and diverse subfamily that is especially abundant in the tropics. The Illinois fauna is quite small compared with that of the entire world.

20. **Atta** Fabricius

This and the following genus belong to a New World tribe called the leaf-cutting ants. The reddish-brown workers cut off pieces of leaves, carry them into the nest, work them into a pulpy mass, and seed them with fungus spores. The ants feed only on the fungus produced by these underground gardens. A mature colony contains thousands of individuals, including a large-headed soldier caste and several sizes of workers. The ants forage in columns; a column of returning workers is a curious sight, each ant carrying a piece of leaf nearly as large as itself. This leaf-carrying habit has earned these ants the name of parasol ants.

The leaf-cutting ants are almost entirely tropical, with two genera extending northward into the south-central states. The genus *Atta* occurs north to central Louisiana.

21. **Trachymyrmex** Forel

This small genus is represented in Illinois only by *T. septentrionalis* (McCook), the northern leaf-cutting ant. It occurs only in sandy soil and makes relatively small nests, each having only a few hundred workers.

22. **Strumigenys** F. Smith

This and the following genus belong to a worldwide, distinctive tribe of minute ants whose workers and queens have long, pointed heads. The workers are dark reddish brown and range in size from 1.5 to 2.5 mm. They occur only in wooded areas, making small nests in rotten wood and foraging in leaf mold. They feed on springtails and other minute organisms. The sole North American species of this genus, *S. louisianae* Roger, occurs in Illinois (Fig. 24*A* and *B*).

23. **Smithistruma** Brown

Several species of this genus occur in Illinois woodlands. In general habits and appearance they resemble *Strumigenys*, but have shorter mandibles (Fig. 24*C* and *D*; Fig. 25).

24. **Wasmannia** Forel

This genus is represented in North America and Illinois only by *W. auropunctata* (Roger), an introduced tropical species that occurs this far north only in houses or greenhouses. The dark workers are minute, only 1.5–1.8 mm, but sting severely, earning them the name little fire ants. They nest in soil and under cover, often with several queens and several thousand workers in a nest. They feed on honeydew, minute insects, and a wide variety of domestic foods.

25. **Harpagoxenus** Forel

Of the two North American species only *H. americanus* (Emery) is known from Illinois. The reddish-

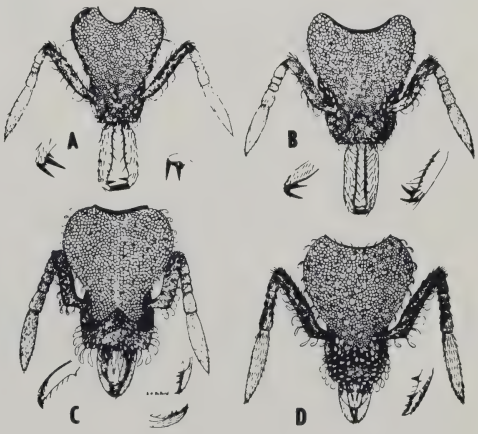

Fig. 24.—Front views of heads of workers. *A, B, Strumigenys louisianae* Roger, showing variation; *C, Smithistruma angulata* Smith; *D, Smithistruma pergandei* Emery. Inset are details of the mandibles. (After M. R. Smith)

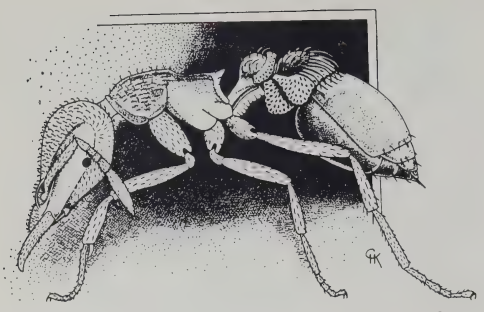

Fig. 25.—Worker of *Strumigenys ohioensis* Kennedy and Schramm, showing the soft, white, funguslike growths that occur on the petiole in many species of this genus. Actual size, 2 mm. (After Kennedy and Schramm)

brown workers are fairly large, ranging in length from 3.0 to 3.5 mm, and forage in leaf mold, under bark, and on low vegetation. This species does not make a nest of its own. Instead, it takes over nests of the genus *Leptothorax*. The *Leptothorax* queen is killed, and the *Leptothorax* workers then assist in raising the brood of the *Harpagoxenus* queen. This genus does not normally inhabit gardens or houses.

26. **Crematogaster** Lund

Several native species of this genus are extremely common in Illinois. The workers (Fig. 26) usually have red heads and black abdomens, and range in size from 2.5 to 4.0 mm. They are easily recognized by the broad head and wide, heart-shaped gaster. These ants nest under stones or other objects on the ground, in dead stumps or logs, and sometimes in posts and rafters, but never in the ground. The colonies may contain several thousand workers. They are general foragers and abundant both in the garden and house, feeding on a variety of domestic foods. In the garden they are often found tending aphids. When disturbed, they bite and sting painfully.

27. **Solenopsis** Westwood

The only Illinois species of this genus is the native *S. molesta* (Say). The workers are dark brown and minute, ranging from 1.3 to 1.8 mm. The nests are usually deep in the ground and each may have several thousand workers. These are among the commones of garden and household ants, feeding on a variety c domestic foods and often eating garden seeds.

To this genus also belong the fire ants, several specie of which occur south of Illinois. These ants are chiefl agricultural, and when disturbed, bite and sting pair fully.

28. **Monomorium** Mayr

The two Illinois species of this genus, the native *M minimum* (Buckley) and the introduced Pharaoh's an *M. pharaonis* (Linnaeus) (Fig. 27), are among ou tiniest ants, the workers ranging from 1.2 to 2.0 mm Both species nest in the soil or in buildings and a frequently abundant in houses, where they eat a varie of domestic food. Pharaoh's ant is especially fond of fa The introduced species, *M. destructor* (Jerdon), occu to the south of Illinois and may eventually be found the state. It also is a domestic pest that causes troub by removing insulation from electric cables and cutti holes in fabrics and rubber goods; it also inflicts a pai ful sting.

Key to Species of Monomorium Workers

1. Segments of the antennal club successively increa ing in length ..... **destruct**
   First two segments of the antennal club about t same size, the terminal segment larger .....
2. Clear reddish yellow ..... **pharao**
   Shining black ..... **minimu**

29. **Pogonomyrmex** Mayr

The ants of this genus are the native agricultural a famous throughout the Great Plains. None has so been taken in Illinois, but they are known not to the west. The workers are chiefly reddish brown a large, ranging from 4.5 to 12.0 mm in length. They n in the ground, constructing a mound of gravel son times 45 cm in diameter and clearing all vegetati around it to a distance of about 1 meter. When d turbed, the workers have a potent sting. These a feed chiefly on seeds supplemented by general scave ing.

30. **Aphaenogaster** Mayr

This large native genus is represented in Illinois about six species. The workers are very slender a

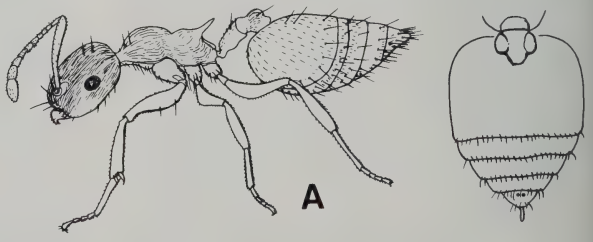

Fig. 26.—Worker of *Crematogaster lineolata* (Say). *A*, side view; *B*, dorsal view of petiole and gaster.

long legged, are usually reddish brown, and vary in size from 3.2 to 7.0 mm. They forage in leaf litter above the ground and in low vegetation, feeding on a variety of foods. They nest in rotten wood, under stones, and in the soil, often making a slightly elevated area on the soil where they have deposited particles from the nest excavation. Each nest may have up to 3,500 workers and several queens.

These ants are frequently abundant in the garden; only rarely does one get into the house. If they locate a nest in a lawn, they may be a persistent nuisance for some time and will frequently inflict painful bites when disturbed. Otherwise, they are not pests.

31. **Myrmecina** Curtis

The two North American species, both native, occur in Illinois. The workers are reddish brown and range in size from 2.5 to 4.5 mm. They construct small nests in rotten wood or leaf litter, primarily in woodlands. They are only rarely found in homes.

32. **Stenamma** Westwood

The three Illinois species of this genus are all natives, similar in size and general appearance to those of the preceding genus. They make their nests chiefly in leaf mold and are restricted to woodland situations.

33. **Pheidole** Westwood

This is primarily a southern genus, having over 40 North American species of which only 2 have been found n Illinois. The workers are dark brown and range in ize from 2.5 to 4.5 mm. The nest is made under stones or in soil, commonly with openings between cracks in idewalks. Each nest may contain several hundred vorkers. The small workers have normal-sized heads, he larger workers greatly enlarged heads with massive nandibles, and these differences are correlated with their ood habits. They naturally feed primarily on small lant seeds that are brought into the nest by the smaller vorkers and then cracked into fragments by the large-eaded workers. Around homes these ants nest commonly n the garden and frequently enter the house, where they eed on a variety of domestic foods.

4. **Myrmica** Latreille

Of the 11 native American species, 4 occur in Illinois. he workers are reddish brown and range in length from .5 to 6.0 mm. They build nests in the soil, each nest sually containing only 50–100 workers and one queen. he workers forage in litter and low-level vegetation. lthough they usually occur in woodlands, they may at mes be common in lawns.

5. **Tetramorium** Mayr

Only a single native species of this genus occurs in llinois, *T. caespitum* (Linnaeus), the pavement ant. The orkers are almost black, 2.5–3.5 mm long. The nests re made in soil, often under stones, boards, or sidewalks. n the house the workers eat a variety of domestic foods; in the garden they may steal seeds and girdle the stems of garden crops.

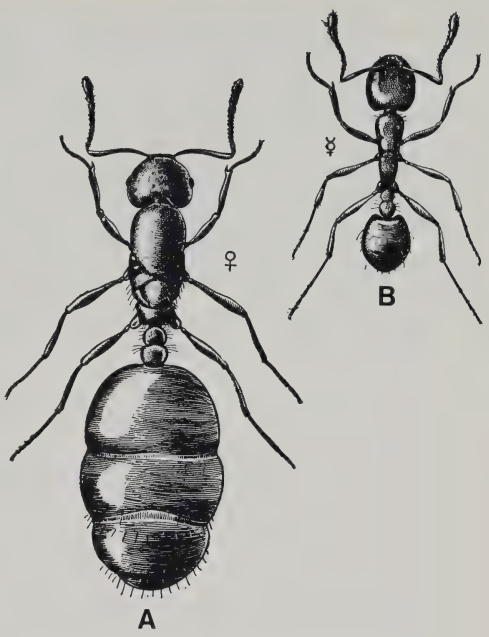

Fig. 27.—Pharaoh's ant, *Monomorium pharaonis*. *A*, queen after losing her wings; *B*, worker. Natural size of queen, 4 mm; of worker, 2 mm. (From USDA)

36. **Leptothorax** Mayr

This abundant North American genus is represented in Illinois by three native species. The workers are usually pale yellow, generally with a dusky spot on each side of the gaster, and range in size from 1.5 to 3.5 mm. They nest in a variety of places, including under rotten wood, under bark, in acorns, and under stones, each nest containing at most a few hundred workers. They are general scavengers, foraging in ground litter and low vegetation. Although their nests may frequently be found in the garden, they very seldom enter the house.

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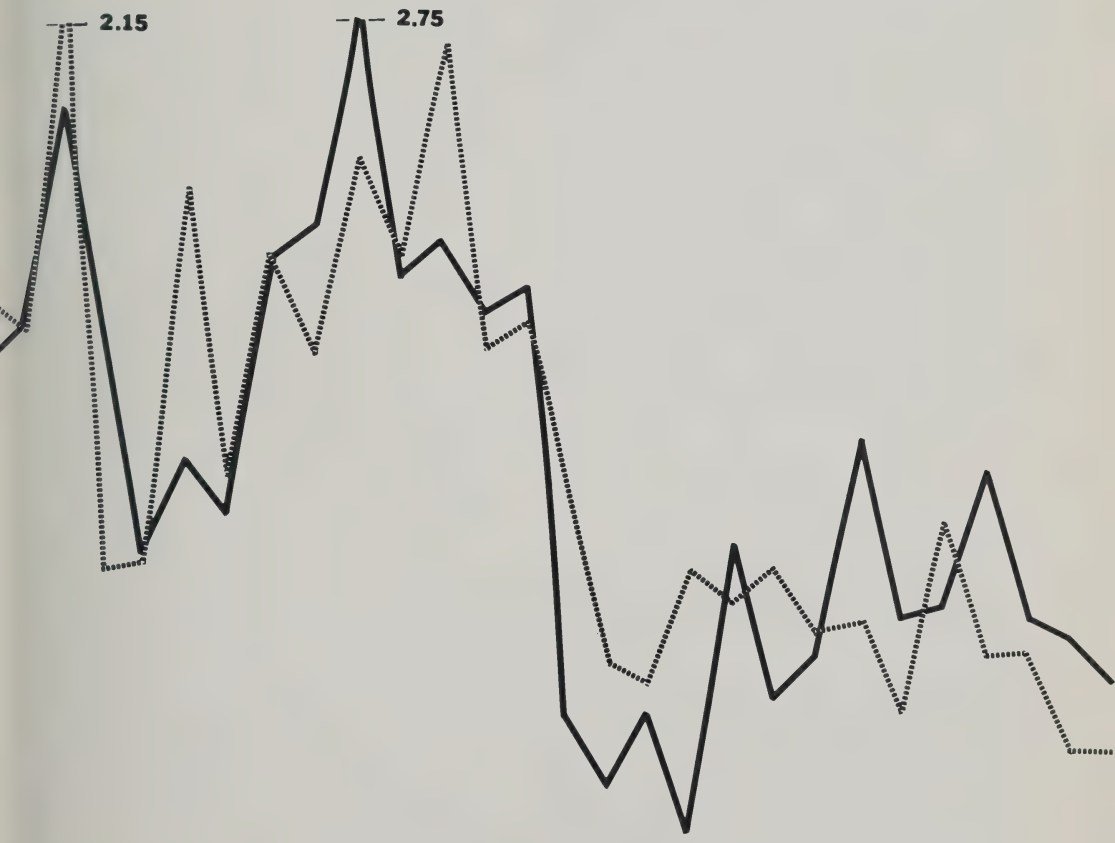
STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION

The Use of Factor Analysis in Modeling Natural Communities of Plants and Animals

Robert W. Poole



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The Problem of Modeling Communities of plants or animals can be studied either by observing the characteristics of the community as a whole or by determining the interactions among and within individual species. At the community level most attention has been focused on descriptive community analysis, species diversity, and energy flow. At the one- and two-species levels some aspects of the problem that have been, and are being, intensively studied are population demography, predation, competition, parasitism, and spatial distribution. These basic interactions have been reasonably well described, and they have been integrated in the modeling of spruce budworm populations in Canada (Morris 1963). However, even this one-species model is very complex and requires the determination of a large number of parameters.

It is just as conceivable to go from the community level to the individual species as from the species to the community. The purpose of this paper is to explore this approach using a statistical technique known as factor analysis. Factor analysis is a statistical technique for picking out the underlying factors causing the variance in a set of variables.

Factor analysis originated in the psychological sciences but is now also being used in the biological sciences. Its first uses in biology were by Goodall (1954) and Sokal & Hunter (1955), and it has since been used extensively in numerical taxonomy (e.g. Sokal & Sneath 1963; Schnell 1970) in the delimiting of the natural associations of plants (e.g. Dagnelie 1965) and in palaeoecology by Reyment (1963).

Factor analysis, primarily the form known as principal components analysis, has been used in biology for the most part as a classification technique, although there have been some attempts to make associations between environmental variables and species using correlation coefficients in a factor-analysis framework (e.g. Dagnelie 1965). Factor analysis was originally developed to estimate and define the factors causing the observed responses in a series of variables and is here used in this sense rather than as a classification technique.

This paper is divided into three parts. The first gives a brief review of basic ecological principles necessary for the following two sections. The second section describes the statistical procedures considered and the analysis of a specific example. The third section considers the assumptions of the factor analytic model and compares them to the initial ecological generalities to see if the model really does mirror the workings of the community or if it only produces a set of mathematically correct but ecologically meaningless numbers. I have tried to emphasize the implications of the assumptions underlying the factor analysis and deemphasize the mathematics. Many university computing centers have the programs used in this paper, and interested persons can find the mathematics underlying the technique in Harman (1967).

I wish to express my appreciation to those persons who have either read the manuscript or helped with the analysis of the example used in this paper: Dr. George F. Kawash of the Department of Psychology, University of Illinois; Dr. K. W. Dickman of the SOUPAC office of the Department of Computer Science, University of Illinois; Dr. Robert H. Whittaker of the Division of Biological Sciences, Cornell University; Dr. Richard B. Root of the Department of Entomolgy, Cornell University; Mrs. Kathleen Eickwort of the Department of Entomology, Cornell University; and my wife Beverly. I also wish to thank Dr. Philip W. Smith and O. F. Glissendorf of the Illinois Natural History Survey for their editorial contributions to the paper.

FACTORS AND SPECIES POPULATIONS

A population of an animal rarely stays at a constant level; usually it is either increasing or decreasing. Whether and how much a population increases or decreases depends on the environmental factors controlling the limits of that population. If conditions are favorable, the population increases; if they are not favorable, it decreases. A species population can be affected by several factors, and the factors may be interacting among themselves. This basic relationship is diagrammed in Fig. 1. Not all of the factors are of equal importance to the species population, one factor usually being more important than the others. If the effect of a factor on a population depends on the density of the population, it is referred to as a density-dependent factor, and if it does not depend on density, it is referred to as a density-independent factor.

In a community of two or more species, a factor influencing one species may also influence other species in the community. The effect of this common factor may vary from species to species, being more important

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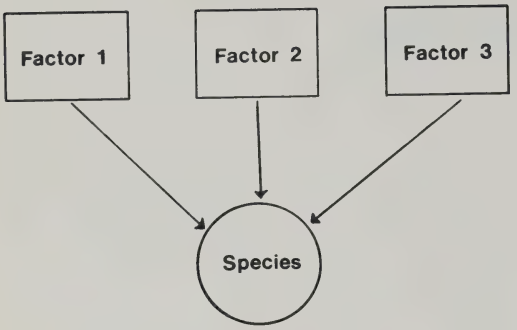

Fig. 1.—Diagrammatic representation of the influence of three factors on one species.

for one than for another. At the same time a species may be influenced by a factor or set of factors which affect it only. These will be referred to as specific factors. This relationship is diagrammed in Fig. 2. Even in this relatively simple community with uncorrelated factors, the complexity is evident.

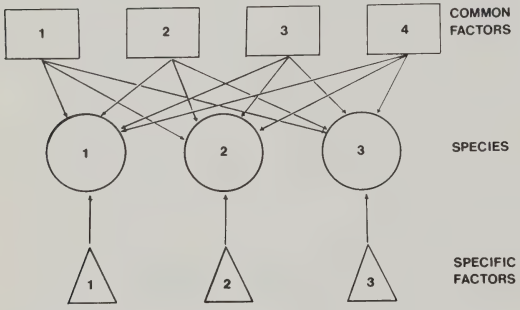

Fig. 2.—Diagrammatic representation of the influence of three specific and four common factors on three species.

If two species share a common factor or factors, the changes in their populations will be correlated. For example, if two species are both limited by rainfall and rainfall is increased, both populations will increase. However, if one species is only slightly dependent on rainfall and the other strongly so, the changes will be disproportionate and the correlation less. As a simple principal rule, the correlations among a group of species making up a community are determined by the species' mutual association with a group of common factors.

In essence, factor analysis takes a matrix of correlation coefficients among a set of variables and reduces it to a series of mathematical common factors that account for the correlations among the variables.

TECHNIQUES

The procedures carried out in this paper are calculation of the correlation matrix, estimation of communalities (the amount of variance caused by factors common to other species), factoring of the matrix using the principal axis method, rotation to a specified hypothesis (transformation of the numbers to other biologically meaningful numbers), calculation of factor scores, and the formulation of the so-called specification equations for each species to serve as a model of the community. If all of the above steps except the factoring of the calculated correlation matrix are skipped, the result is a form of factor analysis normally referred to as principal components analysis.

Principal Components Analysis

Mathematically, factor analysis resolves a correlation matrix (a covariance matrix can also be used in some cases) into a $n \times k$ factor matrix where the number of factors, k, is usually smaller than n, the number of variables (in this case species). This factor matrix has the characteristic that when multiplied by its transpose (rows and columns interchanged) it restores the original correlation matrix. In matrix notation

$$R = V_0 V_0'$$

where R is the correlation matrix, V_0 the factor matrix and V_0' the transposed factor matrix. Basically the problem is to resolve the correlation matrix into its latent roots and vectors (also referred to as eigenvalues and eigenvectors).

Principal components analysis assumes that all of the variance of each species can be accounted for by a set of factors common to all of the other species in the community and lumps variance due to specific factors and error factors in with the common factors. In the actual computation, the loadings (weights) of the first factor on each species (the latent vector or eigenvector) are calculated in such a way as to remove the maximum amount of variance from the matrix as can be explained by one factor. The effects of this factor are then subtracted from the correlation matrix. A second factor is then calculated from this reduced correlation matrix and so forth until the reduced correlation matrix consists of essentially all zeros.

These calculations have been carried out on data given by Hunter (1966). Hunter measured the species populations of *Drosophila* at several sites in Colombia principally near Bogotá. I have analyzed her data from "Pine Woods," a government-protected pine forest near Bogotá. The census was carried out from September 1961 to December, 1963 (28 months) by sweeping a net over bait. In Hunter's table for Pine Woods, the figures for each month are lumped, and the abundance of each species expressed as a percentage of the total *Drosophila* community. In cases where a species frequency was less than 1 percent, it is listed only as present. In my analysis when a species is listed as "present," I have considered it to be absent because individuals of that species made up less than 1 percent of the total. Of the 11 species listed by Hunter, I have analyzed only 10 because the 11th, "*dreyfusi* 22," was very ra

TABLE 1. — Correlations among the frequencies of 10 species of *Drosophila* over a period of 28 months at Pines Woods (near Bogotá, Colombia).

	melanogaster	*pseudoobscura*	*bandeirantorum*	*"tripunctata* 20"	*hydei*	*immigrans*	*viracochi*	*mesophragmatica*	*brncici*	*gasici*
melanogaster	1.00									
pseudoobscura	.37	1.00								
bandeirantorum	.34	.85	1.00							
"tripunctata 20"	−.01	.46	.52	1.00						
hydei	−.08	−.09	.02	−.00	1.00					
immigrans	.09	.24	.31	.57	−.18	1.00				
viracochi	.11	−.13	−.00	−.32	.38	−.02	1.00			
mesophragmatica	−.42	−.79	−.80	−.55	−.09	−.56	−.21	1.00		
brncici	.43	.45	.61	.28	−.09	.05	−.15	−.41	1.00	
gasici	−.13	−.20	−.18	.37	−.01	.58	.01	−.26	−.25	1.00

The correlation matrix was calculated (Table 1) using the Pearson product-moment correlation coefficient and factored using the principal axis method. The resulting factors are shown in Table 2, which also shows

TABLE 2. — Calculated factors from the principal components analysis.

Factor	Variance	Percent Variance	Cumulative Percent
1	3.7921	37.9214	37.9214
2	1.9637	19.6365	57.5579
3	1.5131	15.1310	72.6889
4	0.9162	9.1621	81.8510
5	0.7103	7.1034	88.8544
6	0.5365	5.3646	94.3189
7	0.2941	2.9414	97.2603
8	0.1728	1.7282	98.9885
9	0.0971	0.9712	99.9596
10	0.0040	0.0403	100.0000

that the first three factors account for about 73 percent of the variance in the correlation matrix. The total number of factors extracted by the principal axis method cannot exceed the number of variables. Each of the calculated factors is affected in part by the inclusion of error variance and variance due to specific rather than common factors. Therefore the factors become more and more trivial and unreliable as the factoring proceeds, so that the factors calculated after the first few have no real meaning. A commonly used breaking point in factoring is when the eigenvalue of the factor falls below 1.00 (listed under variance in Table 2). Using this criterion, the first three factors are significant. The factor loadings of each factor on the 10 species are given in Table 3. Factor loadings are a type of correlation between a factor and a variable, or more specifically, the weight of each factor in accounting for the variance of a given variable. In other words if factor 1 had a loading of .47 on a given variable,

TABLE 3. — Computed factor loadings from the principal components analysis on the 10 species of *Drosophila*.

	Factor 1	Factor 2	Factor 3
melanogaster	−.4750	−.3843	−.0687
pseudoobscura	−.8581	−.2522	.0020
bandeirantorum	−.9002	−.2406	.1279
"tripunctata 20"	−.6886	.4540	−.1654
hydei	.0789	−.0303	.7648
immigrans	−.5498	.6897	−.0449
viracochi	.1171	.0108	.8662
mesophragmatica	.9091	−.1325	−.3291
brncici	−.6233	−.4481	−.1364
gasici	−.0914	.8906	.0226

and factor 2 a loading of .03, factor 1 would be more important to the variable than would factor 2.

Rotation

The set of factors arrived at in the preceding section and the loadings of the factors on the variables are only one of an essentially infinite number of possibilities. In other words there is an infinite number of factor matrices that when multiplied by their transpose will restore the original correlation matrix. The factors as they come out of the principal axis method are orthogonal to each other (uncorrelated). These calculated factors do not necessarily correspond in any way with the real attributes of the environment controlling the fluctuations of the species populations. One of this infinite array of answers is the correct one, however, and the problem is to find it. The variables can be plotted on each factor as has been done in Fig. 3 for factors 1 and 2. Factor 3 could be included and the variables would then be in a three-dimensional space. The addition of a fourth factor would be in hyperspace. Any of the possible solutions to the problem can be arrived at by rotating these axes (factors) and reading off the new factor loadings on each variable. This is an oversimplified explanation of rotation and a more complete account can be found in Cattell (1965) and Harman (1967).

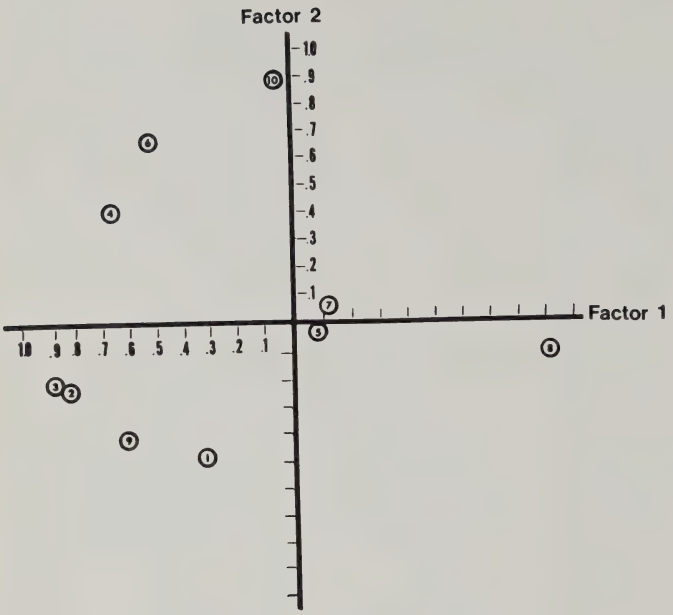

Fig. 3.—Loadings of the 10 species of *Drosophila* on factors 1 and 2.

In the principal axis method the first factor is calculated to account for as much of the variance in the correlation matrix as possible. The method attempts to have this factor loaded as heavily as possible with all of the variables. It is possible that a factor such as temperature would influence all of the species strongly, and in this case the calculated factor as it comes from the analysis would accurately reflect the actual environmental factor. However, it is also possible that a factor may be important to only two or three species and relatively unimportant to the others in a community. In this second case the factors coming from the principal axis analysis would not fit the real situation and must be rotated to a position where they do. The above situation is satisfied by rotation to what is known as simple structure. The factors coming from the principal axis analysis are orthogonal to each other, but very often, probably usually, the factors operating on the species are correlated with each other. By rotating to simple structure, the factors are allowed to be correlated with each other. Mathematically, rotation to simple structure attempts to correlate a factor with the smallest number of variables possible. In other words each factor should affect only a few variables.

In rotation, the original factor matrix (V_0) is multiplied by a transformation matrix (T) giving a new matrix referred to as the reference vector matrix (V_{rs})

$$V_{rs} = V_0 T$$

The reference vector matrix does not give the new loadings of the factors on the variables for reasons discussed by Cattell (1965). To calculate the new factor loadings, a new matrix termed the factor-pattern matrix is calculated as

$$V_{fp} = V_{rs} D^{-1}$$

where D is the diagonal matrix of the reciprocal square roots of the diagonal elements of the inverted matrix of the reference-vector correlations. The reference correlations are computed by multiplying the transformation matrix by its transpose

$$C_{rs} = T' T$$

where C_{rs} is the matrix of correlations between the reference vectors, T the transformation matrix, and T' the transpose of the transformation matrix.

Several mechanical programs are available for rotation to simple structure. The program Oblimax (Pinzka & Saunders 1954) was found to give the most reasonable answers in this case and has been used in this

Table 4. — New factor loadings (the factor-pattern matrix) after rotation to simple structure using the Oblimax program on the 10 species of *Drosophila*.

	Factor 1	Factor 2	Factor 3
melanogaster	−.5791	.2648	−.0889
pseudoobscura	−.8942	.0453	−.0339
bandeirantorum	−.9589	.0280	.0925
"tripunctata 20"	−.4056	−.6187	−.2004
hydei	−.1262	.0744	.7833
immigrans	−.2098	−.8148	−.0725
viracochi	−.0988	.0462	.8881
mesophragmatica	.8618	.3365	−.2956
brncici	−.7255	.2903	−.1641
gasici	.2786	−.9021	.0152

analysis. The factor-pattern matrix after rotation to simple structure is shown in Table 4. A comparison of Tables 3 and 4 shows few significant changes because of rotation to simple structure, using the Oblimax program (the signs have been changed in factor 2).

The new factors produced by rotation to simple structure are not necessarily orthogonal and may be correlated (oblique). The correlation matrix of these three factors is given in Table 5.

TABLE 5. — Correlations among the factors after rotation to simple structure using the Oblimax program.

	Factor 1	Factor 2	Factor 3
Factor 1	1.0000	−.1875	−.1987
Factor 2	−.1875	1.0000	.0469
Factor 3	−.1987	.0469	1.0000

Communalities

In the principal components analysis 1's are entered in the diagonal of the correlation matrix because the correlation of a variable with itself is 1. In factoring the matrix this presumes that all of the variance of a species can be accounted for by factors common to other species. However, a species is normally affected not only by common factors, but by factors specific to it, and also error factors.

The variance of a species (σ^2_s) is equal to the variance explicable by common factors (σ^2_{hs}) plus the variance of the species due to specific factors (σ^2_{us}) plus an error term (σ^2_{es}),

$$\sigma^2_s = \sigma^2_{hs} + \sigma^2_{us} + \sigma^2_{es}$$

The term σ^2_{hs} is usually referred to as a variable's communality.

To remove the variance of a species due to specific factors and error terms, communalities for each species must be calculated and substituted for the diagonal elements of the correlation matrix. Unfortunately there are many different techniques used to estimate communalities and none of them is "the best." Also, the subject of communalities is a controversial one.

In a practical sense, with large initial matrices the effect of not calculating communalities on the estimates of the factors is minimal and becomes less and less important for larger and larger matrices. The calculated communalities are important, however, in estimating the reliability of the predictive equations presented later.

Communalities in the factor analysis carried out in the following pages were calculated by replacing the diagonal entry for each row by

$$(r^*_{ik})\ (S_i - r^*_{ik}) \ /\ (S_k - r^*_{ik})$$

where

r^*_{ik} = maximum absolute r_{ij}

S_i = absolute r_{ij}

S_k = absolute r_{kj}

The calculated communalities are listed in Table 6. Other techniques of communality estimation were tried: (1) replacing the diagonal entry of a variable by the square of the multiple R of each variable with all other variables, and (2) replacing the diagonal entry of a row by the square root of the average r^2 across the row. The estimated communalities using these two methods are also given in Table 6. The Varimax-rotation program (Kaiser 1958) also gives iterative solutions for the communalities. The calculated communalities using this iterative technique are also given in Table 6.

TABLE 6. — Estimated communalities of the 10 species of *Drosophila* using the following methods: 1) $(r^*_{ik})\ (S_i - r^*_{ik}) / (S_k - r^*_{ik})$, 2) square of multiple R, 3) square root of average r^2, 4) iterative.

	1	2	3	4
melanogaster	.2919	.8454	.4075	.3780
pseudoobscura	.8338	.9825	.5499	.7999
bandeirantorum	.8638	.9097	.5708	.8846
"tripunctata 20"	.7150	.7567	.4940	.7077
hydei	.2333	.5736	.3484	.5921
immigrans	.8314	.7779	.4669	.7801
viracochi	.6267	.9399	.3671	.7641
mesophragmatica	.9345	.9932	.5795	.9524
brncici	.4282	.6633	.4592	.6079
gasici	.4036	.9522	.4113	.8021

Factor Identification

The purpose of the analysis is to arrive, mathematically, at a set of factors corresponding to the real factors in the environment that cause changes in populations of the species in the community. This problem has been partially discussed under rotation. There it was shown that factors calculated by the principal axis analysis do not necessarily correspond to any real factors. To make these factors useful, the factor vectors must be rotated in hyperspace to a position where they do correspond to real parts of the environment. The problem of identification can be broken into two stages: (1) rotation of computed factors to where they correlate heavily with real factors of the environment, and (2) the identification of the environmental factors. I will discuss the second stage first.

A set of factors has been calculated that explain part of the variation in the population of a species. However, to be useful these factors must correspond to real parts of the environment that can be identified. Basically we want to know that factor 1 is so highly correlated with rainfall that rainfall, for practical purposes, can be taken as factor 1. Often a person knows *a priori,* or suspects, that species "a" is heavily influenced by some factor such as maximum temperature. Therefore if this species has a heavy loading on one of the factors derived from the factor analysis, it is a good indication that this factor is either maximum temperature or is, in some way, closely correlated with maximum temperature. It is also possible, if measurements of maximum

temperature are available, to include maximum temperature in the data matrices as another variable. If maximum temperature as a variable loads heavily with one factor and little with other factors, it is likely that this factor is in some way related to maximum temperature. Determining the identity of every significant factor is not easy and depends on extensive field work. However, factor analysis indicates how many significant factors to look for, and the weightings of these factors on every species in the community. Even if a factor is interpreted incorrectly, as maximum temperature, the use of maximum temperature measurements for that factor may still give correct predictive answers, a procedure not very scientific but pragmatically important. It must be emphasized that the mathematical factors never exactly correspond to the environmental factors, but they may be so heavily loaded on the environmental factors that measurements of the environmental factors can be used as approximations to the mathematical factors.

The other problem in identification is the rotation of the factors derived from the principal axis method analysis to some position where they correspond to real parts of the environment. If the factors are not rotated, the hypothesis is that the factors tend to influence all of the variables; however, if rotated to simple structure, it is assumed that the real factors tend to influence significantly only a few of the variables. In a real situation neither hypothesis may be the correct one. For example, if in a community of insects rainfall was important to all of the species, but at the same time each species was restricted in its choice of food plants, there would be one factor influencing all of the species, and several other factors that influenced only a few variables each. This situation clearly does not fit the hypothesis behind the factors as they come from the principal axis analysis or after rotation of the factors to simple structure.

It is also possible to rotate the factors to fit a specific hypothesis, but because it is not possible to formulate a specific hypothesis for the example used in this paper, this rotation has not been done. The most difficult problem connected with this type of community analysis should now be apparent. To rotate the calculated factors to a position where they represent real factors of the environment, a correct hypothesis of the type of factors involved and the relative numbers of each (such as two factors influencing all of the species and three factors influencing only two or three species) is needed. The problem is what stage in the identification of factors is to be carried out first—the identification of factors or the rotation of the calculated factors to fit actual factors in the environment. Each is partially dependent on the other. As a working technique it should be possible, by extensive field work and experimentation, to formulate a rough hypothesis as to the percentage of significant factors that will influence a limited number of the species. For example, it might be known that rainfall influences a certain number of species, and there is reason to believe that it is important to virtually all the species in the community. On the other hand, it might be known that most species in the community tend to be limited in their selection of food plants. Given four significant factors, a rough hypothesis might be that one factor influences all of the species, and three others influence only a few of them. From the set of calculated factors, the first (the one accounting for the most variance) is likely to be factor 1 of the hypothesis, with the other three factors being fitted to the groups of species that they load most heavily with. The factors could then be rotated to fit the rough hypothesis, and the hypothesis could possibly be reformulated as a result of the rotation.

Every possible rotation of the factor vectors is, of course, an approximation to the real situation. Some of the approximations will be good, others not so good. A question of practical importance is whether or not the answers derived from each rotation are much different from each other. The answer to this question will only come through use of the factor-analysis technique. In the example used in this paper, the differences between the factor loadings of the orthogonal factors and the factors rotated to simple structure are slight. It has usually been found in psychology that the changes in factor loadings by rotation to simple structure are slight (Kawash, personal communication). Simple structure rotation tends to rotate out small error factors and is used more for that reason than for the hypothesis it represents (Cattell 1965). Even if the factors are not correctly rotated, the appoximation may still be close.

Computational Procedure

Having carried out a principal components analysis of the data and having partially explained the problems of rotation and communalities, the complete factor analysis will now be carried out. In the following section the predictive equations are formulated and the possible usefulness of the technique is discussed.

As discussed in the preceding section, a possible aid in the identification of the factors is to place measurements of presumed factors into the correlation matrix as variables and then note if any of the calculated factors load heavily on them. Hunter (1966) gave data for rainfall, mean maximum temperature, and mean minimum temperature for each month of her study. She assumed that rainfall was one of the most important factors pointing out that its effect probably acted upon the larvae, or perhaps initiated egg laying in the adults. Hunter stated that the average time for development from egg to adult is about 2 months. Because these three environmental measurements are more likely to be important to the larvae that later give rise to the adults than to the adults directly, the three measurements have been entered as variables with the species with a 2 month lead.

The correlation matrix of the 13 variables was com

TABLE 7.—Correlations among the 10 species of *Drosophila* and 3 environmental variables. with calculated communalities n the diagonal.

	melanogaster	*pseudoobscura*	*bandeirantorum*	*"tripunctata* 20"	*hydei*	*immigrans*	*viracochi*	*mesophragmatica*	*brncici*	*gasici*	min. temperature	max. temperature	rainfall
melanogaster	.35												
pseudoobscura	.37	.90											
bandeirantorum	.35	.85	.80										
"tripunctata 20"	−.01	.46	.52	.63									
hydei	−.08	−.09	.02	−.00	.17								
immigrans	.09	.24	.31	.57	−.18	.71							
viracochi	−.11	−.13	−.00	−.32	.38	−.02	.58						
mesophragmatica	−.42	−.79	−.80	−.56	−.09	−.56	−.21	.97					
brncici	.43	.45	.61	.28	−.09	.05	−.15	−.41	.44				
gasici	−.13	−.20	−.18	.37	−.01	.58	.01	−.26	−.24	.66			
min. temperature	−.13	−.16	−.11	.41	.03	.47	−.11	−.11	−.22	.62	.60		
max. temperature	.21	−.12	−.12	.05	−.09	.29	−.54	.12	.05	.21	.29	.52	
rainfall	−.19	−.28	−.09	.09	−.10	.01	−.21	.29	−.01	−.00	−.06	.05	.07

ıted. Rainfall was not significantly correlated with any the other 12 variables. Communalities were esti- ated, as described earlier in this paper, and the esti- ated communalities were entered in the diagonal of e correlation matrix. The new correlation matrix, th all 13 variables and the estimated communalities the diagonal, is given in Table 7.

This correlation matrix with estimated communali- s was then factored by the principal axis method. The genvalues of the first three factors were 3.60, 2.28, and 38, about the same as in the principal components alysis. The second eigenvalue is slightly higher, and e first and third eigenvalues are slightly smaller, than the principal components analysis (Table 2). There however, a significant drop from the eigenvalue of the rd factor (1.38) to the fourth (.61). Using an asso- ted eigenvalue of 1.00 as a criterion of significance, e loadings of the first three factors were computed and e listed in Table 8. Comparison of Tables 8 and 3 shows few major changes in the first two factors but several in factor 3. None of the three environmental

TABLE 8. — Factor loadings of the first three factors on the species of *Drosophila* and 3 environmental variables.

	Factor 1	Factor 2	Factor 3
anogaster	.4001	−.2122	.2205
udoobscura	.8586	−.3278	.0661
deirantorum	.8675	−.2927	.0106
punctata 20"	.6489	.3999	.0612
ei	−.0495	−.0746	−.3590
migrans	.5451	.6116	−.0763
cochi	−.0852	−.2172	−.7811
ophragmatica	−.9466	−.0052	.3344
cici	.5231	−.3158	.2746
ci	.1217	.7909	−.2287
. temperature	.1066	.7497	−.0947
. temperature	.0181	.4004	.5398
fall	−.1726	.1044	.2062

TABLE 9. — Calculated reference-vector structure matrix after rotation to simple structure using the Oblimax program.

	Reference Vector 1	Reference Vector 2	Reference Vector 3
melanogaster	.3869	.1672	.1778
pseudoobscura	.8813	.1214	.0121
bandeirantorum	.8917	.0705	−.0342
"tripunctata 20"	.4832	−.5052	.1608
hydei	.0509	−.0243	−.3676
immigrans	.3563	−.7173	.0703
viracochi	.1471	−.0075	−.8113
mesophragmatica	−.9562	.3252	.3045
brncici	.5194	.2502	.2109
gasici	−.0577	−.8286	−.0488
min. temperature	−.0889	−.7476	.0727
max. temperature	−.2096	−.2173	.6141
rainfall	−.2346	.0042	.2201

TABLE 10. — Calculated factor-pattern matrix after rotation to simple structure using the Oblimax program.

	Factor 1	Factor 2	Factor 3
melanogaster	.3994	.1678	.1841
pseudoobscura	.9097	.1218	.0125
bandeirantorum	.9205	.0708	−.0354
"tripunctata 20"	.4987	−.5068	.1664
hydei	.0525	−.0244	−.3806
immigrans	.3677	−.7196	.0727
viracochi	.1519	−.0075	−.8398
mesophragmatica	−.9870	.3263	.3153
brncici	.5361	.2510	.2183
gasici	−.0596	−.8312	−.0505
min. temperature	−.0918	−.7499	.0753
max. temperature	−.2164	−.2180	.6357
rainfall	−.2422	.0042	.2279

variables is heavily loaded on any of the three factors, although minimum temperature has a moderately heavy loading on factor 2, suggesting that factor 2 may in some way be associated with minimum temperature. Rainfall is lightly loaded on all three factors, and it is thus unlikely that it has any association with the three factors.

The factor matrix was then rotated to simple structure using the Oblimax method, and the resulting reference-vector structure matrix is given in Table 9. The calculated factor-pattern matrix is given in Table 10.

Predictive Equations

The next stage is the formulation of what are known as specification equations. These equations specify the weights to be given to each factor in accounting for the score (observed measurement of some kind) of each variable. The specification equation can be written in a general form as

$$V_{ji} = s_{ji}F_{1i} + s_{j2}F_{2i} + \text{-----} s_{jk}F_{ki} + s_jF_{ji} + s_{je}F_{ei}$$

as given by Cattell (1965). If there are k observations, the score on a variable on one of these observations is equal to the sums of the scores of the factors ($F_{j's}$) influencing the variable as modified by the significance or weight of each factor to the variable (the $s_{j's}$). These factors include a series of common factors, any specific factors there may be, and an error factor. The specification equations will be the basic predictive equations. In the example analyzed in this paper there are 10 species measured at 28 observations, giving a total of 280 specification equations. To formulate the set of equations for all species in the community, it is necessary to calculate first the factor-score matrix (F_p) and secondly the factor-pattern matrix (V_{fp}) which gives the necessary values of the $s_{j's}$.

The factor-score matrix is computed by multiplying the reference-vector structure matrix by the basic diagonal of the original correlation matrix. In computation this step was done by inverting the correlation matrix, multiplying that by the matrix of standard scores for the variables standardized by rows, and multiplying the resulting matrix by the reference-vector structure matrix (V_{rs}) or

$$F_p = V_{rs}\,\delta$$

where F_p is the factor score matrix, V_{rs} the reference-vector structure matrix, and δ the basic diagonal of the correlation matrix. The resulting factor-score matrix for the 28 observations is given in Table 11. The factor scores are the standard scores for the factors calculated for a particular rotation. If the factors have been rotated to where they correspond to real parts of the environment, the factor-score matrix gives estimated standard scores for the environmental factors. If the rotation is not the correct one, the numbers are only numbers that will reproduce the scores on the variables. It is, of course, impossible to use them predictively if they are not real.

Having calculated the factor-score matrix and the factor-pattern matrix, it is now possible to estimate the value of a variable on any observation. As an example, the standard score of *Drosophila pseudoobscura* at observation 4 (December, 1961) equals the sums of t factor scores as weighted by the factor loadings for th period plus specific factor scores, plus an error ter In other words

Drosophila pseudoobscura$_{(4)}$ = (.9097)(.7821) (.1218)(−.1245) + (.0126)(−.7125) + specific fa tors$_{(4)}$ + error factors$_{(4)}$

Drosophila pseudoobscura$_{(4)}$ = .6873 + specific fa tors$_{(4)}$ + error factors$_{(4)}$. All scores are in standa form.

Theoretically if the scores for the common facto the specific factors, and the error factors were known, predicted scores would exactly fit the actual scores the variables (species population levels). However, in t case nothing is known of the specific factors and error factors, and the predictions are based only on variance attributable to common factors. Where co mon factors account for a large percentage of the va ance of a species, the predictions should be fairly ac rate. In a species population influenced to a large tent by specific factors and error factors, the predicti will not be as good. To a certain extent, the reliabi of the estimates can be judged from the size of the s cies population's communality, species with large co munalities being more predictable than those with sm communalties. This procedure, in essence, pretends t specific and error factors do not exist.

Graphs of the predicted and observed abundances standard scores) of the 10 species are given in Fig. 4 It is clear that for many of the species, particularly common ones, predicted and actual values agree qu well, although there are still some deviations. De

TABLE 11. — Calculated factor score matrix for the 28 ob servations from the Oblimax rotation to simple structure.

Observation	Factor 1	Factor 2	Factor 3
1	.4840	1.0297	−.5129
2	.5836	.9663	−1.0332
3	1.7794	.3722	−.6943
4	.7821	−.1245	−.7125
5	−.4793	−.0247	.8224
6	−.1264	.3034	2.3076
7	−.3645	.8503	1.6247
8	1.1017	.4221	.7145
9	1.2421	.0689	−.0601
10	3.2278	−1.3368	−1.9288
11	1.1410	−1.0098	−.6190
12	1.1349	.3455	.5760
13	.8159	−.0459	−.4046
14	.9906	−.3255	−.8530
15	−1.4451	.9605	1.8509
16	−1.9348	1.2871	1.7579
17	−1.2463	.6319	.7126
18	−2.1194	1.3567	2.2356
19	−.3433	−.2672	.0467
20	−1.2586	.4976	1.0491
21	−.4868	−3.9399	.4878
22	.4718	−1.9417	−1.0491
23	−.6639	−.4351	−1.1375
24	−.8399	1.2284	−.1013
25	.0412	.0449	−2.7617
26	−.5968	−.8071	−.5184
27	−.8115	−.2905	−.5392
28	−1.0795	.0832	−.8220

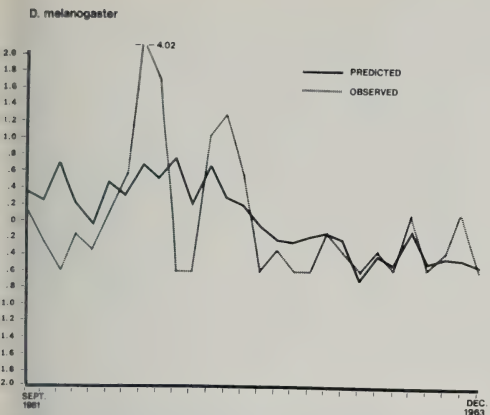

Fig. 4.—Predicted versus observed abundances (standardized) for *Drosophila melanogaster* from September, 1961 to December, 1963.

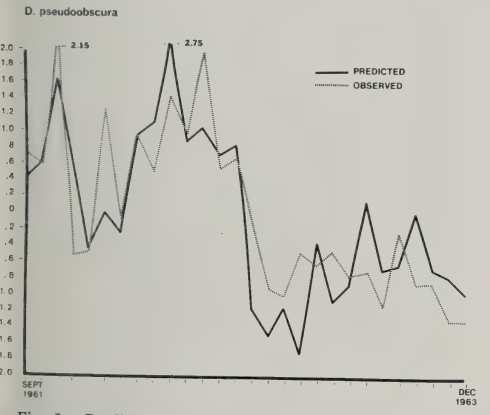

Fig. 5.—Predicted versus observed abundances (standardized) for *Drosophila pseudoobscura* from September, 1961 to December, 1963.

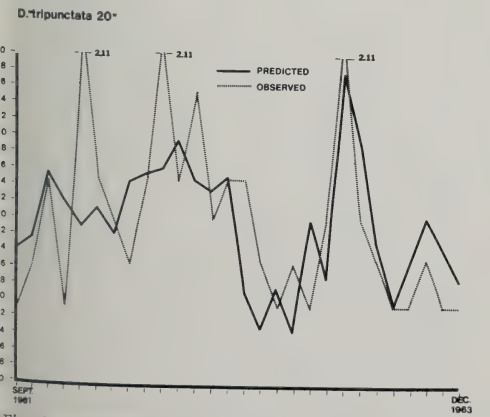

Fig. 6.—Predicted versus observed abundances (standardized) for *Drosophila "tripunctata* 20" from September, 1961 to December, 1963.

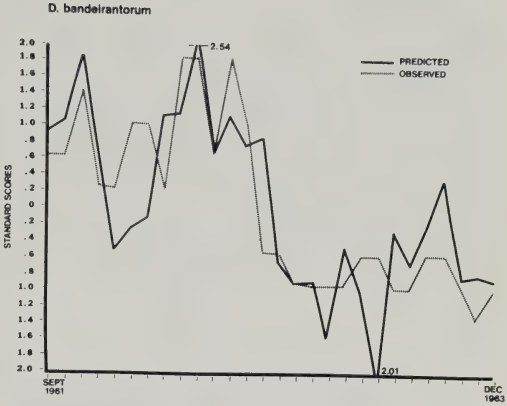

Fig. 7.—Predicted versus observed abundances (standardized) for *Drosophila bandeirantorum* from September, 1961 to December, 1963.

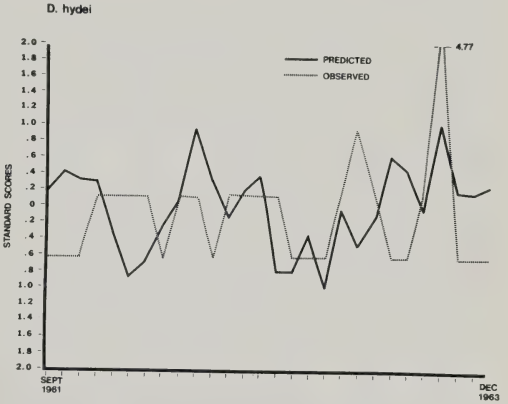

Fig. 8.—Predicted versus observed abundances (standardized) for *Drosophila hydei* from September, 1961 to December, 1963.

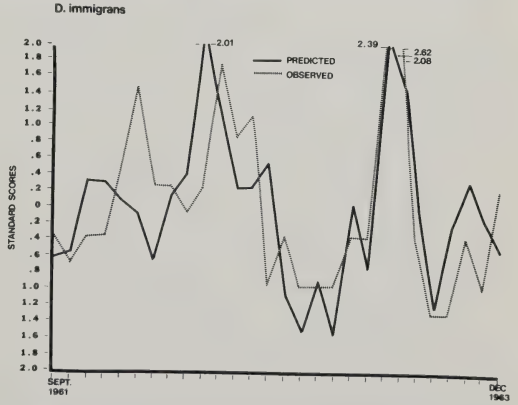

Fig. 9.—Predicted versus observed abundances (standardized) for *Drosophila immigrans* from September, 1961 to December, 1963.

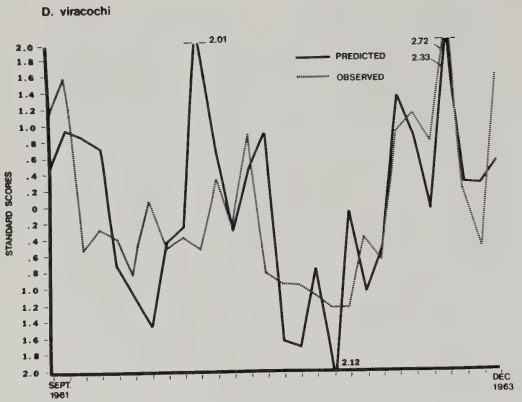

Fig. 10.—Predicted versus observed abundances (standardized) for *Drosophila viracochi* from September, 1961 to December, 1963.

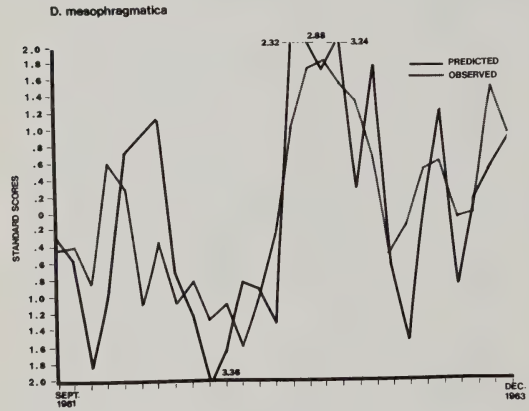

Fig. 11.—Predicted versus observed abundances (standardized) for *Drosophila mesophragmatica* from September, 1961 to December, 1963.

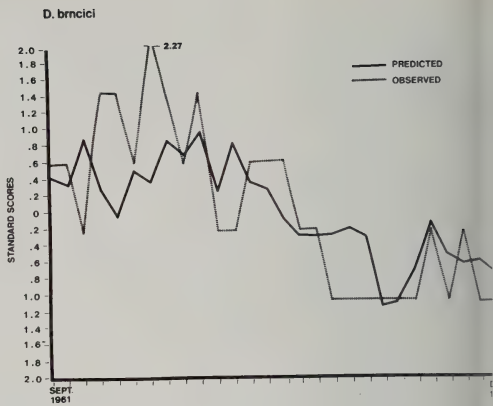

Fig. 12.—Predicted versus observed abundances (standardized) for *Drosophila brncici* from September, 1961 to Decem ber, 1963.

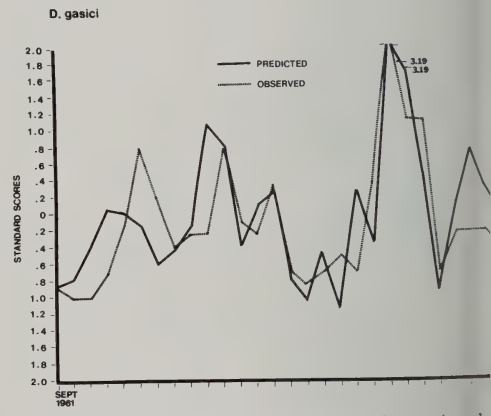

Fig. 13.—Predicted versus observed abundances (standardized) for *Drosophila gasici* from September, 1961 to Decemb 1963.

tions of the predicted from the actual values (with the predicted values converted to raw scores), as measured by a Chi-square goodness-of-fit test for *Drosophila pseudoobscura* and *mesophragmatica,* are highly significant; the fit is hardly perfect.

Some general observations are:

1. Common species are better modeled than rarer ones.
2. Large, long-term changes can usually be predicted, but short-term, small fluctuations cannot, particularly for the rarer species.
3. The last 14 months present a better fit than the first 14 months.

In a practical sense the predicted population levels from the above analysis are rather trivial because values of a set of common factors were calculated from 28 observations on 10 variables (species); using these calculated factor scores, the population levels of the spec for each period were recalculated. However, if the f tors influencing the species of a given community h been identified by a previous factor analysis and the tation properly carried out, it is possible later to m measurements of the factors, standardize them, and t calculate predicted standard scores for all of the spe of the community using a set of specification equati as above. I have not been able to do so with these d from the literature, because the factors have not b identified, or if they had been, no measurements available for them. Also, there is no way to check validity of the results.

The use of these predictive equations can be illustr ed by a possible application. A factor-analysis study ried out on the community of fish in a river had de mined that water temperature was one of the import

actors affecting the fish community. It is also known hat the establishment of a nuclear reactor on the banks f the river will progressively raise the temperature of he water. The question is: "How will the rise in tem- erature of the water affect the populations of the fish ving in the river?" The expected rises in temperatures ith time could be entered into the specification equa- ons. The other factors could be assumed to be constant estimates of their probable values might be entered, d the predicted population levels of all species of fish the river estimated for time x. A weakness of the odel is that it can never predict a species becoming tinct although it will approach zero frequency as a nit.

DISCUSSION

Like any other statistical technique, factor analysis anipulates data in an attempt to reveal the underlying uses and their importance to the variables measured. hree important assumptions are made about the data hen factor analysis is employed (Cattell 1965): (1) dividual variables and factors are linearly interrelated,) two factors act additively in respect to any given riable, and (3) there are no interaction effects among e variables.

No assumptions are made about the distributions of e variables. Various tests for significance of factors do ke assumptions regarding the distributions of variables d, for that reason, have been avoided in this paper. It robable that in any real, relatively large community organisms all three assumptions will be violated at e time or another. Because of the likelihood of some vilinear or higher polynomial relationships between tors and variables and because of the existence of non- ditive factors, it is important to know how closely the ear model assumed by the factor analysis approximates situation where there are some nonlinear relation- os between variables and factors.

Cattell & Dickman (1962), using variables and tors between which the relationships were known, wed that if variables are not linearly related to the tors, the factor analysis approximates the determina- n of the variable by representing a product by a sum. er a small range this is usually considered to be a good roximation. For example, if a species were deter- ed by two factors acting multiplicatively,

$$\text{Species} = sF_1F_2$$

n the factor-analysis model approximates it by

$$\text{Species} = sF_1 + sF_2$$

After the analysis has been carried out and the num- and nature of the factors determined, the linear lel can be modified and the predictions improved by erimentally locating nonadditive factors and modify- the series of specification equations. The same can lone with nonlinear relationships between variables factors. Often the mathematical relationship of a factor to a community of species, if not linear, will be roughly the same for all species (i.e. if the relationship is exponential, it will be exponential for all species).

Two other common situations that modify the relationships between factors and variables are threshold levels and competition for a limited resource. Sometimes a factor influencing a set of variables may operate only above or below a critical value. For example, dispersal in some animals occurs when the population of a species reaches a critical density. The sigmoid curve of population ecology assumes that reaction to increasing density is gradual: the closer the population approaches the carrying capacity of the environment, the slower the rate of growth. It is also possible that there may be a situation where the curve is completely exponential until the carrying capacity has been reached, or surpassed, and a point is reached where density-dependent factors act suddenly. In some predators, search images are formed on abundant species of prey and, when the population of a prey species reaches a critical level, a predator population may begin to attack it to the exclusion of other less common species.

Competition between the members of a community may prove to be more of a problem, and depends on whether populations are controlled by density-dependent or density-independent factors. It is the author's opinion that both types of factors are important in animal communities. One factor influencing a group of species in a community may be a common food resource, such as in a group of insects all feeding on the same species of plant. In the situation of two insect species feeding on one plant species, the feeding of species "a" reduces the amount of factor "X" (the plant) and therefore indirectly influences species "b," the other species feeding on the same species of plant. Factors of this type are referred to as "expendable" and, when they are shown to exist, the specification equations can be modified to take them into account.

The computational steps in the factor analysis technique presented in this paper are outlined in Fig. 14. The assumptions underlying each step of the procedure have been discussed in the Techniques section and will

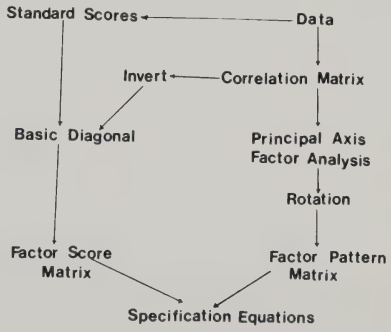

Fig. 14.—Sequence of steps in creating a factor analytical model of a community.

not be repeated here. The experimental steps can be roughly outlined as: (1) definition of the "community" of animals or plants or both to be studied, (2) carrying out of the census, (3) running of the factor analysis, (4) identification of the factors and rotation to a specified hypothesis, (5) formulation of the specification equations (first approximation), (6) discovery and analysis of nonlinear, factor-variable relationships and of nonadditive factors (second approximation), and (7) discovery and measurement of specific factors for each species (third approximation).

As the size of the community studied increases, the number of significant common factors discovered also increases. By increasing the number of species measured, a factor originally specific to one species may now influence a second species and can be picked out by the factor analysis. As more species are considered, more factors must be identified.

Because of the tremendous amount of field work and experimentation needed for this technique, the decision to stop at the first, second, or third approximation will depend on how close the first approximation accurately predicts future changes (or spatial changes) in the species of the community and on how much time and money are available.

A rough approximation is often all that is needed. A farmer usually wants to know only which species, any, of a set of possible pests will be abundant enou to damage his crops, given a set of conditions that h can predict (e.g., will the application of a certain pes cide in the spring cause an increase in the populatio of some potential pest species later in the year?). H is not particularly interested in the exact level of ea population.

The factor analysis technique is applicable to mod ing communities in both space and time. The fact analysis approach is an improvement over the multip regression approach (actually a form of factor analysi in indicating not only how many factors to look f but also which species are influenced by which fact and the extent of the influences. The psychologists ha also found empirically (Kawash, personal communic tion) that the results of a factor analysis modeling of siutation using the specification equations tend to much more useful when applied to similar situatio (such as perhaps a model of one river being more a plicable to the fishes in an adjacent river), than are t multiple regression equations.

Factor analysis is an extensive and complicated su ject. Just how useful this proposed technique will pro can only be known after it has been more extensiv used and studied.

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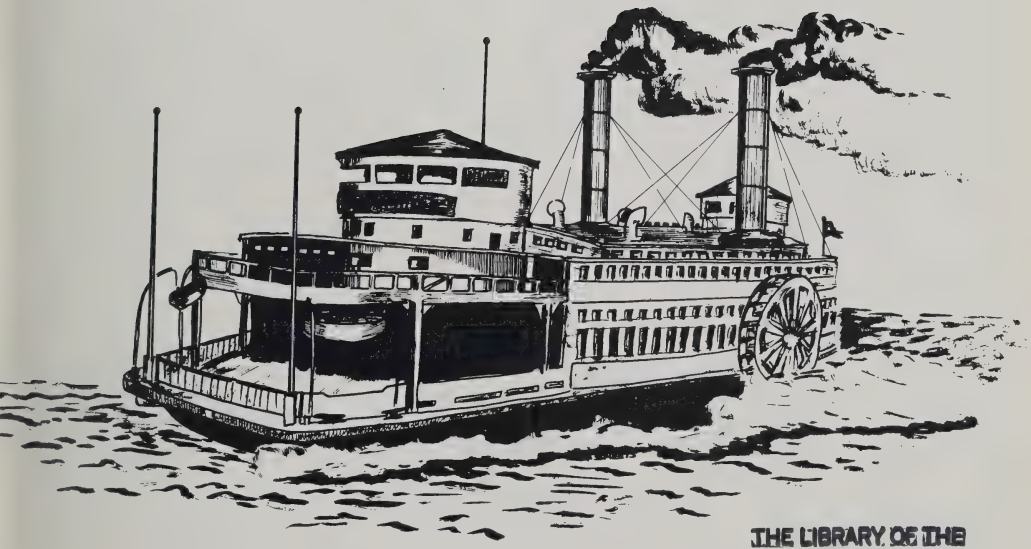
DISTRIBUTIONAL ATLAS
F UPPER MISSISSIPPI RIVER FISHES

IP W. SMITH
N C. LOPINOT
LIAM L. PFLIEGER



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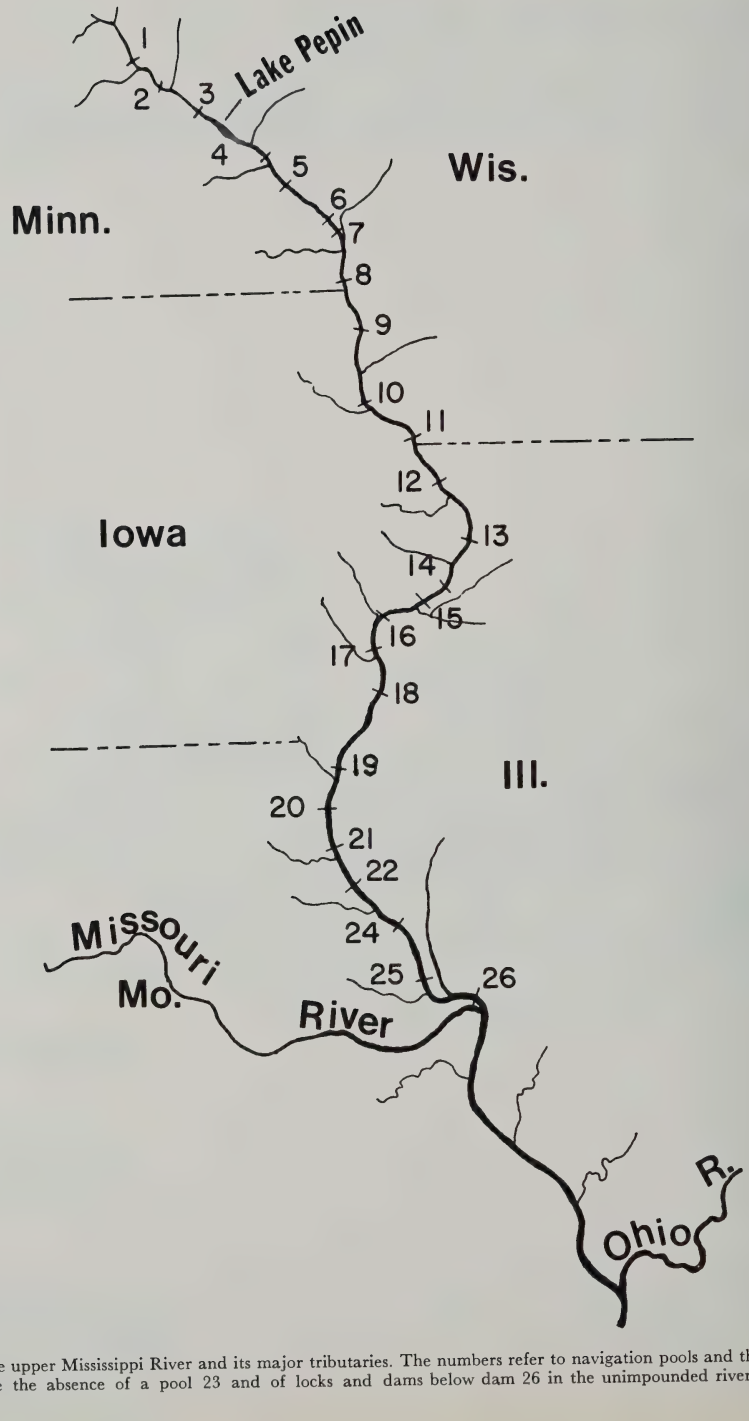

Fig. 1.—The upper Mississippi River and its major tributaries. The numbers refer to navigation pools and their downstream loc
and dams. Note the absence of a pool 23 and of locks and dams below dam 26 in the unimpounded river, referred to as B-2

A DISTRIBUTIONAL ATLAS OF UPPER MISSISSIPPI RIVER FISHES

Philip W. Smith, Alvin C. Lopinot, and William L. Pflieger

GROWING CONCERN OVER POLLUTION and habitat alteration in the Mississippi River prompts us to publish information we have assembled on the present distribution of fishes in that river. Since 1962 a concerted effort, under the aegis of the Upper Mississippi River Conservation Committee (hereafter UMRCC), has resulted in a vast quantity of distributional data, and its publication can provide a criterion that will aid in the detection and measurement of future changes in the environmental quality of the river.

The upper Mississippi River, as defined in this report, extends from river mile 0 at the mouth of the Ohio River near Cairo, Illinois, to river mile 854 at St. Anthony Falls near Minneapolis, Minnesota. River miles are indicated on the navigation charts (Middle and Upper Mississippi River, U.S. Army Engineer Division, North Central Corps, 1963), and they are prominently posted along the river banks so that the numbers are readily visible as a navigation aid to boat and barge pilots in the river channel.

Most of the upper Mississippi River consists of navigation pools separated by numbered locks and dams (Fig. 1). Each pool takes the same number as its downstream lock and dam. Pool 1, for example, lies between St. Anthony Falls and lock and dam 1; pool 2, between lock and dam 1 and lock and dam 2, etc. Since there is no lock and dam 23, there is no pool 23. The lowermost combined lock and dam is number 26; lock 27 and dam 27 are at different locations on the river. In the fisheries literature the pool between lock and dam 25 and lock and dam 26 is termed pool 26, and the river below dam 26 is called B-26. Below dam 27 the river is unimpounded.

In the Mississippi River, commercial and sport fishes have received considerable attention from researchers (UMRCC 1945–1968; Barnickol & Starrett 1951; Carlander 1954; Starrett & Barnickol 1955; and Nord 1967). Other fishes, which comprise well over half of the total number of species known to occur in the Mississippi, have received less attention, and detailed information on their distribution and abundance in the river is not generally available. Many of these fishes are small and difficult to identify, but they can serve as indicators of biological conditions in the river when the assemblage of species and their numerical relationships are known.

HISTORICAL RESUMÉ

Prior to the establishment of the present UMRCC in 1943, knowledge of the fish fauna of the river was based largely on the work of Meek (1892), Forbes & Richardson (1908), Greene (1935), specimens deposited in the Museum of Zoology at the University of Michigan, old reports of federal and state fish commissions and the U.S. Bureau of Fisheries, and scattered publications citing records from the Mississippi River. For an excellent summary of early investigations, see Carlander (1954).

With the establishment of the UMRCC, its Fish Technical Section inaugurated field operations early in 1944. These investigations continued through 1946 and involved personnel and financial support from the conservation departments of Missouri, Iowa, and Illinois and the Illinois Natural History Survey. The 2-year investigation of the river between Caruthersville, Missouri, and Dubuque, Iowa, culminated in the publication of *Commercial and Sport Fishes of the Mississippi River* (Barnickol & Starrett 1951).

Aware of the need for a list of all of the fishes in the upper Mississippi River, the UMRCC asked Dr. Reeve M. Bailey of the University of Michigan to compile an official guide for common and scientific names for all species. Bailey's mimeographed preliminary list, a remarkably accurate prediction of species that have since been found in the river, was based at least in part on specimens submitted to him for identification by Barnickol and Starrett and other UMRCC collectors. The list appeared in the proceedings of the eighth annual meeting (UMRCC 1952). A table showing the distribution of fish species for pools 3–11 also appeared in the proceedings of the eighth annual meeting and was revised the following year (UMRCC 1953) by Drs. John Greenbank and Raymond E. Johnson.

Subsequent issues of the mimeographed UMRCC proceedings added a few new distributional records, and Robert C. Nord canvassed old literature and the member agencies of UMRCC for all fish distributional records for the river. In 1962 we proposed to the Fish Technical Section of the UMRCC that a cooperative small-fishes survey of the river be undertaken in 1963 by personnel of the member agencies of the committee. It was our hope that a number of intensive minnow-seine collections would provide information on the small fishes and would supplement the information on commercial and sport fishes in Barnickol & Starrett's (1951) bulletin. In 1963 biologists from the Illinois and Iowa conservation departments made over 100 minnow-seine collections and a few otter-trawl collections, and biologists from the Missouri Conservation Department sampled intensively a dozen sites in their part of the river. The Wisconsin and Minnesota departments of conservation subsequently sent in a few additional collections, but the need for more sampling was obvious.

In 1964 and 1965 staff members of the Natural History Survey made a few more collections in the Illinois portion of the river. Dissatisfied with the species representation in many of the collections, we again approached the UMRCC Fish Technical Section and proposed that mouths of preselected tributaries be sampled the following summer by seining and electrofishing. Col-

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lections were made at the mouths of 63 tributaries by agencies from all five member states of the UMRCC during the summer of 1966, and the results were summarized in a mimeographed compendium of the upper Mississippi River fisheries (Nord 1967).

Since 1967 the Missouri Conservation Department has contributed the results of its investigations of the lower part of the river, and a few recent collections have been secured by Illinois Natural History Survey and Missouri Conservation Department personnel and by Larry Dunham, the biologist assigned to the river by the Illinois Department of Conservation. As a result of the UMRCC cooperative effort since 1962, collections are available for virtually the entire upper river (Fig. 2).

Fig. 2.—Locations of collecting stations sampled since 1962. At each site one to many minnow-seine collections were made, and at many of them electrofishing samples were also taken.

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SOURCES OF DATA

A distribution map is provided for each species kno from three or more sites in the upper Mississippi Riv Records for specimens personally examined by one us are plotted with a solid symbol. A few of them da back to 1944, but most are based on specimens tak since 1962. Specimens for most records are deposited the collection of the Illinois Natural History Survey; certain other records specimens are located in the U versity of Kansas Museum of Natural History and t University of Michigan Museum of Zoology. In a f cases records are based on large specimens that w identified and then returned to the river.

Supplemental records based on specimens not se by one of us are plotted with hollow circles. Beca the emphasis in this paper is on present distribution, hollow symbols represent the most recent published r ords available from each locality. The source for ea hollow circle on the maps can be determined by c sulting the corresponding account in the list of spec where the sources are indicated. Published records t we regard as questionable and certain quite old reco are discussed in the annotated list but are not plot on the maps.

ANNOTATED LIST OF SPECIES

An asterisk preceding the name of a species den that we regard its presence in the river as acciden

The scientific and common names used follow Bailey (1970). The families of fishes are arranged in phylogenetic sequence, following the classification proposed by Greenwood et al. (1966). Within each family, however, genera and species are listed in alphabetical order. For each species a statement about its present distribution is given, and supplemental records and their sources are listed.

Ichthyomyzon castaneus Girard.—The chestnut lamprey is occasionally taken from pool 20 downstream to the mouth of the Ohio River, but it is extremely sporadic, if still present at all, above pool 20. Supplemental records for pools 7–9 (UMRCC 1953) and 4, 5, 10, and 11 (Nord 1967), but based on specimens collected almost 20 years ago, are available. Starrett, Harth, & Smith (1960:342) noted that in Illinois the species no longer occurred as far north as its type-locality (Mississippi River, Galena, Illinois), but in Wisconsin recent records are available from the Fox and Yellow rivers (George C. Becker, personal communication, August 10, 1970).

Ichthyomyzon unicuspis Hubbs & Trautman.—The silver lamprey is occasionally taken from pool 10 downstream to the mouth of the Ohio River, but it is uncommon below the mouth of the Missouri River. Supplemental records are available for pools 5 and 7–9 (UMRCC 1953). Although our opinion is based on specimens collected nearly 20 years ago, we believe the species still occurs above pool 10.

Acipenser fulvescens Rafinesque.—The lake sturgeon s rare in the river. In 1966 an Illinois commercial isherman secured two specimens near Quincy that had combined weight of 56 pounds, and a Missouri fisherman caught a 32-pound specimen near Elsberry. Supplemental records are as follows: pools 4, 8–10 (UMRCC 953), 3, 6, 17, 19, 20, and 22 (Nord 1967).

Scaphirhynchus albus (Forbes & Richardson).—The allid sturgeon is extremely rare. It is represented by small specimen given to Barnickel & Starrett (1951: 90) in 1944 by a fisherman, who caught the fish near he mouth of the Missouri River (the type-locality), and small specimen secured at river mile 75 in the spring f 1970. A record for Keokuk (Coker 1930) is not ccepted because it is quite old. There is no other vidence of the occurrence of the pallid sturgeon in he Mississippi above the mouth of the Missouri River.

Scaphirhynchus platorynchus (Rafinesque). — The hovelnose sturgeon is taken occasionally from Lake Pepin o the mouth of the Ohio River. Supplemental records re as follows: pools 4 (UMRCC 1965), 5–6 (UMRCC 968), 7–9, 12, 14, 18–20, 25, 26 (UMRCC 1955), 10, 1, 13, and 15 (UMRCC 1960).

Polyodon spathula (Walbaum).—The paddlefish is ken occasionally from pool 9 downstream to the mouth the Ohio but is rare in the upper pools. Supplemental cords exist for pools 4, 5 (UMRCC 1953), 6, 8 (Nord 967), 9 (UMRCC 1958), 10–15, 17–20, 22, 24 (UM CC 1961), 25, 26 (UMRCC 1963), and B-26 (Barckol & Starrett 1951).

Lepisosteus osseus (Linnaeus).—The longnose gar is nerally distributed and seemingly more common above an below the mouth of the Missouri River. Supplental records are as follows: pools 3–5 (UMRCC 1964), 8–10 (UMRCC 1953), 11, 13, 16, 17, 19, 24, and B-26 (Barnickel & Starrett 1951).

Lepisosteus platostomus Rafinesque.—The shortnose gar is widely distributed and especially abundant below the mouth of the Missouri River. Supplemental records are available for pools 2–5 (UMRCC 1964), 6, 8, 9 (UMRCC 1953), 7 (UMRCC 1958), 11, 12, 14, 15, 25 (Barnickel & Starrett 1951), 16, and 17 (Starrett & Barnickel unpublished).

Lepisosteus spatula Lacépède.—The alligator gar is rare. In addition to the published records of Barnickel & Starrett (1951), photographs of a 130-pound specimen from Cairo and a 110-pound specimen from Chester, both caught by Illinois commercial fishermen in 1965, are available through the kindness of Mr. O. M. Price of the Illinois Department of Conservation.

Amia calva Linnaeus.—The bowfin is widely distributed and seemingly more common in the impounded pools above the mouth of the Missouri River than below. Supplemental records are as follows: pools 3–6, 25, 26 (UMRCC 1963), 7, 8, 22 (UMRCC 1961), 9, 10, 20 (UMRCC 1960), 11, 13, 16, 17, 24 (UMRCC 1964), 12 (UMRCC 1966), 14, 15, 19, B-26 (Barnickel & Starrett 1951), and 21 (UMRCC 1965).

Anguilla rostrata (Lesueur).—The American eel is occasionally taken from Lake Pepin to the mouth of the Ohio River. Supplemental records are available for pools 5, 12, 13, 22 (UMRCC 1964), 7, 21, 24, 25 (UMRCC 1963), 8 (UMRCC 1953), 9 (UMRCC 1955), 10 (UMRCC 1957), 11 (UMRCC 1965), 14, 16, 17, B-26 (Barnickel & Starrett 1951), 15 (UMRCC 1966), 18 (UMRCC 1961), and 19 (UMRCC 1960).

Alosa alabamae Jordan & Evermann.—The Alabama shad is extremely rare and is represented by one small specimen taken in 1962 in a seine haul at river mile 152. An old record for Keokuk, reported as *A. ohiensis* by Coker (1930), has not been plotted.

Alosa chrysochloris (Rafinesque).—The skipjack herring is moderately common near the mouth of the Ohio River and occasional as far upstream as pool 15. Supplemental records are: pools 13 (UMRCC 1958), 16, 17 (Nord 1967), and 20, 21 (Barnickel & Starrett 1951). Other early published records are not plotted.

Dorosoma cepedianum (Lesueur).—The gizzard shad is abundant throughout the river. There is a supplemental record for pool 2 (UMRCC 1965).

Dorosoma petenense (Günther). — The threadfin shad is moderately common near the mouth of the Ohio River.

Hiodon alosoides (Rafinesque).—The goldeye is common from pool 20 downstream to the mouth of the Ohio and especially common below the mouth of the Missouri River. Supplemental records are as follows: pools 3, 4, 6, 11 (UMRCC 1953), 5, 8, 10, 12, 13, 18, 24, 25 (Nord 1967), 14, 17, and 19 (Barnickel & Starrett 1951).

Hiodon tergisus Lesueur.—The mooneye is widely distributed but is much more common above pool 20 in less turbid pools than it is below pool 20. Supplemental records exist for pools 3–5 (UMRCC 1964), 6–11 (UMRCC 1953), 14, 15 (Barnickel & Starrett 1951), 12, 13, 16–21, 22, 24, and 25 (Nord 1967).

**Salmo gairdneri* Richardson.—A specimen of the

rainbow trout, collected in 1969 from pool 14, is clearly a stray from a tributary. Supplemental records for pools 7, 9, and 10 (Nord 1967), undoubtedly also stragglers from tributaries, are available.

**Umbra limi* (Kirtland).—The mudminnow, recorded from pools 7–9 (UMRCC 1953), probably is accidental in the river proper.

**Esox americanus* Gmelin.—The grass pickerel, although represented by several collections, is rare, and the specimens may have been stragglers from overflow ponds. Supplemental records for pools 9, 10 (UMRCC 1953), 17 (Nord 1967), 18 (UMRCC 1948), 25 (UMRCC 1951), and 26 (Barnickol & Starrett 1951) are available.

Esox lucius Linnaeus.—The northern pike is moderately common upstream from pool 11 and occasional downstream as far as the mouth of the Ohio River. Supplemental records are: pools 2 (UMRCC 1965), 3–5 (UMRCC 1964), 13 (UMRCC 1967), 14, 15, 17 (Barnickol & Starrett 1951), 16 (UMRCC 1960), 18 (UMRCC 1954), and 19 (UMRCC 1956).

Campostoma anomalum (Rafinesque).—The stoneroller is widely distributed but is distinctly uncommon. If there are permanent populations, they are localized in shallow runs and chutes, and it is possible that the occasional specimens are stragglers from small tributaries of the river. Supplemental records are available for pools 4, 7, 11 (UMRCC 1953), 10 (Becker 1966), and 17 (Nord 1967).

**Dionda nubila* (Forbes).—In 1963 a specimen of the Ozark minnow was seined at river mile 68 and another at mile 121, both on the Illinois side. If these fish came from tributaries, they crossed the river, for the species is not otherwise known in southern Illinois although it is common in Missouri streams.

Cyprinus carpio Linnaeus.—The carp is an abundant and important fish throughout the river. Supplemental records are as follows: pools 5, 17 (UMRCC 1963), 11 (UMRCC 1964), and B-26 (Barnickol & Starrett 1951).

**Ctenopharyngodon idella* (Valenciennes).—A 34-inch, 21-pound male specimen of the grass carp was caught at Chester, Illinois, by commercial fisherman Paul DeSherlia in January 1971. This species, recently introduced in the southern states, has found its way into the Mississippi River and, according to fishermen, has since been caught at other sites.

Ericymba buccata Cope.—A few specimens of the silverjaw minnow were taken in the minnow seine at two sites (river miles 41 and 105) in 1963.

Hybognathus argyritis Girard.—A few specimens of this minnow were collected at several sites between the mouths of the Missouri and Ohio rivers. This species, recently rediscovered by Pflieger (1971), is widespread in the Missouri River system.

Hybognathus hankinsoni Hubbs.—The brassy minnow has been recorded from pools 3, 4, 6, and 9 (UMRCC 1953). It is also reported from several sites upstream from pool 1 (Underhill 1957).

Hybognathus nuchalis Agassiz.—The silvery minnow is relatively common between Lake Pepin and pool 14 and below the mouth of the Missouri River, but it has not been taken at all in the intermediate section. Supplemental records for pools 6–8, 10, and 11 (UMRCC 1953) are assignable on geographic grounds to this species, but published records of "*nuchalis*" below the mouth of the Missouri River cannot be so assigned.

Hybognathus placitus Girard.—The plains minnow is moderately common in the silt-laden part of the river below the mouth of the Missouri.

Hybopsis aestivalis (Girard).—The speckled chub is represented by several specimens in most of the minnow-seine collections made below Lake Pepin. Supplemental records are as follows: pools 6, 8–11 (UMRCC 1953), 7 (Nord 1967).

Hybopsis gelida (Girard).—The sturgeon chub is extremely rare and is confined to that part of the river below the mouth of the Missouri. A supplemental record from pool B-26 (Starrett & Barnickol unpublished) is available.

Hybopsis gracilis (Richardson).—The flathead chub is represented in virtually every minnow-seine collection made below the mouth of the Missouri River.

Hybopsis meeki Jordan & Evermann.—The sicklefin chub is uncommon but is represented by a few specimens in several collections taken below the mouth of the Missouri River.

Hybopsis storeriana (Kirtland).—The silver chub is common throughout the river. Supplemental records are available for pools 5–9 (UMRCC 1953).

Hybopsis x-punctata Hubbs & Crowe.—The gravel chub is rare but is represented in three recent minnow-seine collections made below the mouth of the Missouri River.

**Nocomis biguttatus* (Kirtland).—The hornyhead chub is represented by one specimen in a 1963 collection from pool 4. It is widely distributed above pool 1 (Underhill 1957).

Notemigonus crysoleucas (Mitchill).—The golden shiner is widely distributed but not common. Supplemental records are as follows: pools 6–8, 11 (UMRCC 1953), 16, and 20 (Nord 1967).

Notropis amnis Hubbs & Greene.—The pallid shiner is rare at present. Supplemental records for pools 3, 5, 9, 11 (UMRCC 1953), and 21 (Starrett & Barnickol unpublished) are available. In view of the present rarity of the species, older records are not plotted, since the species has been decimated in many areas.

**Notropis anogenus* Forbes.—The pugnose shiner is represented by a record for pool 4 (UMRCC 1953) and is probably accidental in the river.

Notropis atherinoides Rafinesque.—The emerald shiner is the most abundant fish in the river. A supplemental record for pool 5 (UMRCC 1953) is available.

Notropis blennius (Girard).—The river shiner is the second most abundant fish in the river, but is somewhat less common below the mouth of the Missouri River than it is above that point. Supplemental records are available for pools 5 (UMRCC 1967) and 6 (UMRCC 1953).

**Notropis boops* Gilbert.—The bigeye shiner is represented in two recent minnow-seine collections (river miles 43 and 327), but it is probably accidental in the river.

Notropis buchanani Meek.—The ghost shiner is widely distributed and rather common below pool 14, but it has become quite rare and may be extirpated above pool 14. Supplemental records, all of which are almost 20 years old, for the upper pools (UMRCC 1953), pool B-26, and B-26 (Starrett & Barnickol unpublished) are available.

**Notropis chrysocephalus* (Rafinesque).—The striped shiner was present in one of our minnow-seine collections and in two of those made by Starrett & Barnickol (unpublished) below the mouth of the Missouri River; these fish probably came from nearby small tributaries.

Notropis cornutus (Mitchill).—The common shiner is recorded from pools 1 (Underhill 1957), 8, 9, 11 (UMRCC 1953), and 10 (Becker 1966). It is reportedly rare below pool 1 but widely distributed above that pool and in the headwaters of the river (Underhill 1957).

Notropis dorsalis (Agassiz).—The bigmouth shiner is widely distributed above the mouth of the Missouri but usually represented by only a few specimens. Supplemental records for the northern pools (UMRCC 1953) and pool B-26 (Starrett & Barnickol unpublished) are available.

Notropis emiliae (Hay).—The pugnose minnow is generally distributed above pool 18 but is usually present only in small numbers. Supplemental records are as follows: pools 3–9, 11 (UMRCC 1953), 16, and 17 (Nord 1967).

Notropis hudsonius (Clinton).—The spottail shiner is widely distributed and rather common above the mouth of the Missouri River, and it is known from several sites above pool 1 (Underhill 1957). Below the mouth of the Missouri it is sporadic and less common. Supplemental records are available for pools 5 (UMRCC 1967), 6, and 7 (UMRCC 1953).

Notropis lutrensis (Baird & Girard).—The red shiner is moderately common from pool 18 to the mouth of the Ohio River.

**Notropis rubellus* (Agassiz).—The rosyface shiner is recorded from pools 6 and 11 (UMRCC 1953) but is probably accidental in the river.

Notropis shumardi (Girard).—The silverband shiner is relatively common near the mouth of the Ohio River, but this species becomes progressively less common upstream.

Notropis spilopterus (Cope).—The spotfin shiner is fairly common from pool 18 upstream into the headwaters (Underhill 1957). The one record for the lower river is probably based on a straggler from a tributary. Supplemental records are as follows: pools 4 and 6 (UMRCC 1953).

Notropis stramineus (Cope).—The sand shiner is widely distributed throughout most of the river, but it is usually present in small numbers. Supplemental records exist for pools 4 (UMRCC 1967) and 6–8 (UMRCC 1953).

Notropis texanus (Girard).—The weed shiner is recorded from pools 5–11 (UMRCC 1953) and 12 (Nord 1967), but it is not common in the river.

**Notropis venustus* (Girard).—The blacktail shiner was taken in a recent minnow-seine collection at river mile 43, but the fish probably came from a tributary.

Notropis volucellus (Cope).—The mimic shiner is common near the mouth of the Ohio River and is present in smaller numbers upstream to the mouth of the Missouri River. It is also recorded from pools 3–11 (UMRCC 1953), but it is apparently rare and may be extirpated in the upper pools. It is not known from the intermediate section of the river.

Phenacobius mirabilis (Girard).—The suckermouth minnow is widely distributed but not common. Supplemental records are available for pools 5, 8–10 (UMRCC 1953), and B-26 (Starrett & Barnickol unpublished).

**Phoxinus erythrogaster* (Rafinesque).—The southern redbelly dace has been recorded from pool 11 (UMRCC 1953). Details are lacking, but the specimen or specimens almost certainly were accidental in the river and probably came from a nearby small tributary.

Pimephales notatus (Rafinesque).—The bluntnose minnow occurs throughout the river, but it is common only in the headwaters (Underhill 1957). Supplemental records are available for pools 2 (Underhill 1957), 3–6, 11 (UMRCC 1953), and 20 (Starrett & Barnickol unpublished).

Pimephales promelas Rafinesque.—The fathead minnow occurs throughout the river but is quite uncommon. Supplemental records are as follows: pools 1 (Underhill 1957), 3–6, 8, 9 (UMRCC 1953), 10 (Becker 1966).

Pimephales vigilax (Baird & Girard).—The bullhead minnow is generally distributed below Lake Pepin and is abundant above the mouth of the Missouri River. A supplemental record for pool 5 (UMRCC 1967) is available.

**Semotilus atromaculatus* (Mitchill).—The creek chub is accidental in the river, except in its headwaters (Underhill 1957). Supplemental records are as follows: pools 3, 8 (Underhill 1957), 4, and 9 (Nord 1967).

**Semotilus margarita* (Cope).—The pearl dace is known from pool 1 and the headwaters of the river (Underhill 1957).

Carpiodes carpio (Rafinesque).—The river carpsucker occurs throughout the river and is particularly abundant below the mouth of the Missouri. Supplemental records for pools 2 (UMRCC 1965), 5 (UMRCC 1964), 6, and 7 (UMRCC 1953) are available.

Carpiodes cyprinus (Lesueur).—The quillback is widely distributed and common, but it is distinctly less common below the mouth of the Missouri River than above the mouth. A supplemental record for pool 6 (UMRCC 1953) is available.

Carpiodes velifer (Rafinesque).—The highfin carpsucker is occasionally taken above pool 14. Supplemental records are as follows: pools 2 (UMRCC 1965), 3, 5, and 6 (UMRCC 1953).

Catostomus commersoni (Lacépède).—The white sucker is widely distributed above pool 12, but it is evidently present only as a straggler below pool 12. Supplemental records exist for pools 2 (UMRCC 1965), 4 (UMRCC 1967), 6–9 (UMRCC 1953), 13, 16 (Nord 1967), 15, and 19 (Barnickol & Starrett 1951).

Cycleptus elongatus (Lesueur).—The blue sucker is

widely distributed but not common. Supplemental records are as follows: pools 4, 6, 8–10 (UMRCC 1953), 5 (UMRCC 1964), 7, 11, 25 (Nord 1967), 15, 16, 21, and 24 (Barnickol & Starrett 1951).

Hypentelium nigricans (Lesueur). — The northern hog sucker is rare and probably present only as a straggler below pool 12. Supplemental records are in existence for pools 4, 6, 9 (UMRCC 1953), 10, 15, 16, and 19 (Nord 1967).

Ictiobus bubalus (Rafinesque).—The smallmouth buffalo is widely distributed and moderately common below pool 12 but rare above. Supplemental records are as follows: pools 2 (UMRCC 1965), 5, 10, 11 (UMRCC 1953), 17, 22, 25, and B-26 (Barnickol & Starrett 1951).

Ictiobus cyprinellus (Valenciennes).—The bigmouth buffalo is widely distributed and moderately common throughout the river. Supplemental records are available for pools 2 (UMRCC 1965), 3–5 (UMRCC 1964), 6–11 (UMRCC 1953), 12, 15, 22, 24, 25, and B-26 (Barnickol & Starrett 1951).

Ictiobus niger (Rafinesque).—The black buffalo is widely distributed and fairly common from pool 14 to the mouth of the Ohio River. Supplemental records are as follows: pools 4–6, 8–10 (UMRCC 1953), 7 (Nord 1967), 11–17, 21, 22, 24, 25, and B-26 (Barnickol & Starrett 1951).

Minytrema melanops (Rafinesque).—The spotted sucker is occasionally taken between Lake Pepin and pool 17. Supplemental records for pools 5 (UMRCC 1964), 9 (UMRCC 1953), 11, and 17 (Barnickol & Starrett 1951) are available; records of presumably greater age for pools 18 and 20 (Nord 1967) are not plotted.

Moxostoma anisurum (Rafinesque).—The silver redhorse is rather rare but is taken most frequently above pool 12. Supplemental records are available for pools 4 (UMRCC 1967), 6–10 (UMRCC 1953), 12, 20 (Nord 1967), and 16 (Barnickol & Starrett 1951).

Moxostoma erythrurum (Rafinesque).—The golden redhorse is rather rare and is taken most frequently above pool 14. Supplemental records are as follows: pools 5, 8 (UMRCC 1967), 6, 9, 11 (UMRCC 1953), 7 (Nord 1967), and 10 (Becker 1966).

Moxostoma macrolepidotum (Lesueur).—The most generally distributed *Moxostoma* in the river, the shorthead redhorse is usually present in small numbers. Supplemental records exist for pools 2 (UMRCC 1965), 5 (UMRCC 1964), 13, 15, 17, 18, 20, 21, and 25 (Barnickol & Starrett 1951).

Moxostoma valenciennesi Jordan.—The greater redhorse is recorded from pools 5 (UMRCC 1964) and 8 (UMRCC 1953). The latter record has recently been confirmed by Dr. R. E. Jenkins of Roanoke College, who examined the specimen on which it was based.

**Ictalurus catus* (Linnaeus).—Adult white catfish, taken near New Boston and near Wolf Lake, Illinois, by commercial fishermen during the summer of 1970, are the first records for the Mississippi River. The specimens are regarded as escapees from stockings at sites near the Mississippi River.

Ictalurus furcatus (Lesueur).—The blue catfish is taken occasionally below pool 26, but it has become rare above the mouth of the Missouri River. The northernmost recent record is for pool 13 (UMRCC 1958). Supplemental records are as follows: pools 13 (UMRCC 1958), 19 (Nord 1967), 20–22, 24, 25, B-26 (Barnickol & Starrett 1951), and 26 (Rock 1963).

Ictalurus melas (Rafinesque).—The black bullhead is widely distributed but not common. Supplemental records are available for pools 3–5 (UMRCC 1964), 6–10 (UMRCC 1953), 11, 14–18, 20, 21, 26, B-26 (Barnickol & Starrett 1951), 12, 24 (Nord 1967), 22, and 25 (UMRCC 1951).

Ictalurus natalis (Lesueur).—The yellow bullhead is widely distributed but not common. Supplemental records are as follows: pools 2 (UMRCC 1965), 5 (UMRCC 1964), 6–11 (UMRCC 1953), 13, 24 (Nord 1967), 17, 18, 21, 25, 26, B-26 (Barnickol & Starrett 1951), and 20 (UMRCC 1951).

Ictalurus nebulosus (Lesueur).—The brown bullhead is recorded from several sites above pool 10. Supplemental records for pools 2 (UMRCC 1965), 3, 5 (UMRCC 1964), 4 (UMRCC 1967), 6, 8, 9 (UMRCC 1953), and 26 (Barnickol & Starrett 1951) are available. Records of unknown age for pools 11 and 13 (Nord 1967) are questionable and not plotted. The published record for pool 26 is probably based on a straggler from the Illinois River, which has populations of the brown bullhead.

Ictalurus punctatus (Rafinesque).—The channel catfish is common throughout the river. Supplemental records are as follows: pools 2 (UMRCC 1965), 3–5 (UMRCC 1964), 9 (UMRCC 1960), 19, and 25 (Barnickol & Starrett 1951).

Noturus flavus Rafinesque.—The stonecat is widely but sporadically distributed. Supplemental records are available for pools 4, 6, 9–11 (UMRCC 1953), 13, and 16 (Nord 1967). Specimens from sites below the mouth of the Missouri River represent the small-eyed phenotype discussed by Taylor (1969:123).

Noturus gyrinus (Mitchill).—The tadpole madtom is widely distributed but usually not common. Supplemental records for pools 6–8 (UMRCC 1953), 21, and B-26 (Starrett & Barnickol unpublished) are available.

Noturus nocturnus Jordan & Gilbert.—The freckled madtom is represented in recent minnow-seine collections from pools 20 and 21, and it probably is restricted to localized rubble riffles.

Pylodictis olivaris (Rafinesque).—The flathead catfish is fairly common throughout the river. Supplemental records are as follows: pools 2 (UMRCC 1965), 3–5 (UMRCC 1964), 6 (UMRCC 1953), 7 (UMRCC 1958), 8–10 (UMRCC 1960), 11, 12, 15–22, 25, B-26 (Barnickol & Starrett 1951), and 13 (Rock 1963).

**Aphredoderus sayanus* (Gilliams). — The pirate perch is recorded from pools 5–9 (UMRCC 1953), but this species is probably rare in the river proper.

Percopsis omiscomaycus (Walbaum). — The trout perch is generally distributed above pool 10 and rather common in Lake Pepin. Supplemental records exist for pools 5, 6, and 8–10 (UMRCC 1953). The southernmost record is for river mile 150 (Starrett & Barnickol unpublished).

Lota lota (Linnaeus).—The burbot is rare and not known to many commercial fishermen. A specimen, taken in a hoopnet near New Boston, Illinois, late in 1969 by commercial fishermen Wesley Long and son, has been presented to us by Mr. Herbe McAtee, vice-president of the Boston Bay Conservation Club in Viola, Illinois. Supplemental records are as follows: pools 3, 5, 9, 11, 25 (Nord 1967), 4 (UMRCC 1964), and 8 (UMRCC 1953).

**Fundulus notti* (Agassiz).—The starhead topminnow is represented by a 1967 collection of eight specimens in pool 26, but it probably does not regularly occur in the river.

Fundulus notatus (Rafinesque). — The blackstripe topminnow is occasionally taken below pool 20. A supplemental record for pool 25 (Starrett & Barnickol unpublished) is available.

**Fundulus olivaceus* (Storer).—The blackspotted topminnow is represented by a 1963 record for the mouth of the Ohio River.

Gambusia affinis (Baird & Girard).—The mosquitofish is taken occasionally below pool 24. A supplemental record for pool B-26 (Starrett & Barnickol unpublished) is available.

Labidesthes sicculus (Cope).—The brook silverside is widely distributed, but this species is much more common above pool 18 than it is below that pool. Supplemental records are available for pools 3–6 (UMRCC 1953).

Menidia audens Hay.—The Mississippi silverside is represented by a 1963 collection at the mouth of the Ohio River.

**Culaea inconstans* (Kirtland).—The brook stickleback is recorded from pools 4 and 7 (UMRCC 1953), but it is probably accidental in the river.

Morone chrysops (Rafinesque).—The white bass is common throughout the river. A supplemental record for pool 5 (UMRCC 1967) is available.

Morone mississippiensis Jordan & Eigenmann.—The yellow bass is widely but sporadically distributed, and it is sometimes locally common. Supplemental records are as follows: pools 6, 13, 20, 22 (Nord 1967), 7 (UMRCC 1960), 14–19 (Barnickol & Starrett 1951), 24 (UMRCC 1958), and 26 (Rock 1963).

Ambloplites rupestris (Rafinesque).—The rock bass is generally distributed above the mouth of the Missouri River; however, it is quite rare except above pool 8, where it is common. Supplemental records for pools 5 (UMRCC 1964), 8, 10, 11, 26 (UMRCC 1960), 12–15, 16, 17, 20, 21, and 25 (Nord 1967) are available.

**Centrarchus macropterus* (Lacépède).—The flier is represented by a specimen from Cairo, Illinois, (Barnickol & Starrett 1951) and is probably accidental in the river.

Lepomis cyanellus Rafinesque.—The green sunfish is widely distributed but not common. Supplemental records are as follows: pools 2 (UMRCC 1965), 5, 6, 8, 11 (UMRCC 1953), 12, 14 (Nord 1967), 15, 18 (Barnickol & Starrett 1951), and 25 (UMRCC 1960).

Lepomis gibbosus (Linnaeus).—The pumpkinseed is common above pool 14. Supplemental records are available for pools 3–5 (UMRCC 1964), 6 (UMRCC 1953), 10, 11, 14, and 16–19 (Nord 1967).

Lepomis gulosus (Cuvier).—The warmouth is widely distributed below pool 5 but quite uncommon. Supplemental records are as follows: pools 6, 9, 10 (UMRCC 1953), 7, 12, 14, 21, 24, 25 (UMRCC 1958), 8 (UMRCC 1960), 11, 16–18, B-26 (Barnickol & Starrett 1951), and 22 (Nord 1967).

Lepomis humilis (Girard).—The orangespotted sunfish is widely distributed and rather common. Supplemental records for pools 3–8 (UMRCC 1953) and 18 (UMRCC 1948) are available.

Lepomis macrochirus Rafinesque.—The bluegill is abundant throughout the river. Supplemental records for pools 5 and 15 (UMRCC 1967) are available.

Lepomis megalotis (Rafinesque).—The longear sunfish is represented in recent minnow-seine collections made near the mouth of the Ohio River, but this species is uncommon in the upper Mississippi.

**Lepomis microlophus* (Günther).—The redear sunfish is represented in a recent seine collection from pool 26, but this fish is probably accidental in the river.

Micropterus dolomieui Lacépède.—The smallmouth bass is widely distributed, but it is rather rare below pool 17. The southernmost record is at river mile 120 (Starrett & Barnickol unpublished). Supplemental records are as follows: pools 5 (UMRCC 1967), 8 (UMRCC 1960), 15, 18, 25 (UMRCC 1958), 16, 20 (Nord 1967), 26 (UMRCC 1952), and B-26 (Barnickol & Starrett 1951).

**Micropterus punctulatus* (Rafinesque).—The spotted bass, taken only below the mouth of the Missouri River, is probably accidental in the Mississippi. A published record for pool 14 (Barnickol & Starrett 1951) is probably based on a misidentification and is not accepted.

Micropterus salmoides (Lacépède).—The largemouth bass is widely distributed and rather common throughout the river. Supplemental records for pools 2 (UMRCC 1965) and 5 (UMRCC 1967) are available.

Pomoxis annularis Rafinesque.—The white crappie is common throughout the river. Supplemental records are as follows: pools 2 (UMRCC 1965), 5 (UMRCC 1964), 16, 17, and B-26 (Barnickol & Starrett 1951).

Pomoxis nigromaculatus (Lesueur). — The black crappie is common throughout the river, especially in the northern pools. Supplemental records are available for pools 5 (UMRCC 1967), 6 (UMRCC 1953), 7 (UMRCC 1955), 24, 25, and B-26 (Barnickol & Starrett 1951).

Ammocrypta asprella (Jordan).—The crystal darter is represented by records for pools 6 (UMRCC 1953) and 8 (Nord 1967) and is extremely rare. A record for pool 11 (Greene 1935:174) is not plotted because of its age.

Ammocrypta clara Jordan & Meek.—The western sand darter occurs between Lake Pepin and the mouth of the Missouri River, and it is locally common. Supplemental records are as follows: pools 5 (UMRCC 1967), 6–8, 10, 11 (UMRCC 1953), and 16 (Nord 1967).

Etheostoma asprigene (Forbes).—The paucity of records of the mud darter is surprising in view of the abun-

dance of the species in some of the large tributaries of the Mississippi River. Supplemental records for pools 4–11 (UMRCC 1953) are available.

**Etheostoma caeruleum* Storer.—A recent record of the rainbow darter in pool 25 is probably based on a straggler from a small tributary.

Etheostoma chlorosomum (Hay).—The bluntnose darter appears to have a northern disjunct population in pools 8 and 9 (UMRCC 1953), but it seems to be accidental in pool B-26.

**Etheostoma exile* (Girard).—The Iowa darter is represented by published records for pools 5, 7, 8 (UMRCC 1953), and 9 (Nord 1967).

**Etheostoma flabellare* Rafinesque. — The fantail darter is probably accidental in the Mississippi River. Supplemental records for pools 4 and 10 (UMRCC 1953) are available.

Etheostoma nigrum Rafinesque.—The johnny darter is widely distributed but rather uncommon. Supplemental records are as follows: pools 5 (UMRCC 1967), 6, 9, and 11 (UMRCC 1953).

**Etheostoma spectabile* (Agassiz).—The orangethroat darter, recently taken in pool 25 and at river mile 43, is probably accidental in the river.

**Etheostoma zonale* (Cope).—The banded darter, recorded from pools 9–11 (Nord 1967), is probably accidental in the river.

Perca flavescens (Mitchill).—The yellow perch is generally distributed above pool 19 and locally common. Supplemental records are available for pools 5 (UMRCC 1964), 8–11 (UMRCC 1960), 15–17 (UMRCC 1958), and 22 (Nord 1967).

Percina caprodes (Rafinesque).—The logperch is widely distributed and rather common in the upper pools. Supplemental records for pools 5 (UMRCC 1967), 6, and 11 (UMRCC 1953) are available.

**Percina maculata* (Girard).—The blackside darter is probably accidental in the river. Supplemental records for pools 4, 5, 8, 9 (UMRCC 1953), and 10 (Becker 1966) are available.

Percina phoxocephala (Nelson).—The slenderhead darter is widely distributed but rare. Supplemental records for pools 4, 6, 7, 9, and 11 (UMRCC 1953) are available.

**Percina sciera* (Swain).—The dusky darter is represented by a 1963 collection from river mile 43, but this species is accidental in the river.

Percina shumardi (Girard).—The river darter is widely distributed, and it is common above the mouth of the Missouri River. Supplemental records for pools 5–10 (UMRCC 1953) are available.

Stizostedion canadense (Smith).—The sauger, widely distributed and common throughout most of the river, is especially common below the mouth of the Missouri River. Supplemental records are available for pools 5 (UMRCC 1967), 13 (Nord 1967), and 26 (Rock 1963).

Stizostedion vitreum (Mitchill). — The walleye is widely distributed, but it is distinctly less common below pool 20 than it is above that pool. Supplemental records are as follows: pools 5 (UMRCC 1967), 6 (UMRCC 1953), 17, 19 (UMRCC 1960), 11, 15, 16 (Barnickol & Starrett 1951), 24, 25 (Nord 1967), and 26 (Rock 1963).

Aplodinotus grunniens Rafinesque.—The freshwater drum is common throughout the river and is particularly abundant below the mouth of the Missouri River. A supplemental record for pool 5 (UMRCC 1963) is available.

**Cottus carolinae* (Gill).—The banded sculpin, taken in 1963 at river mile 70, is accidental in the river.

PROBLEMATIC AND ERRONEOUSLY REPORTED SPECIES

The following species, included in Bailey's preliminary list (UMRCC 1952) because most of them are known to occur in the lower reaches of tributary streams, have not been taken in the Mississippi River: spotted gar, *Lepisosteus oculatus;* brown trout, *Salmo trutta,* muskellunge, *Esox masquinongy*; redfin shiner, *Notropis umbratilis*; blacknose dace, *Rhinichthys atratulus*; longnose dace, *Rhinichthys cataractae*; river redhorse, *Moxostoma carinatum*; spotted sunfish, *Lepomis punctatus* bantam sunfish, *Lepomis symmetricus*; and slough darter *Etheostoma gracile.*

The report of the spotted gar in the "Mississipp River system of Illinois" (Hubbs & Lagler 1941:26) evidently referred merely to the drainage, and a speci men recorded from pool 19 (Anonymous 1962), made available to us through the courtesy of Dr. Kenneth D Carlander of Iowa State University, is reidentified as an aberrant specimen of the shortnose gar.

The brown trout is, as Bailey suggested, likely to be found eventually as a straggler in the river.

The muskellunge, reported from pools 10, 17 (Nord 1967), and 9 (Greene 1935) but presumably based on old records, probably does not now occur in the river.

The redfin shiner, blacknose dace, and longnose dace are abundant in a number of tributaries, and it is surprising that recent specimens of these species have not been represented among the many thousands of minnows we have examined from the Mississippi River.

The river redhorse occurs in Lake St. Croix (Phillips & Underhill 1967:177), and it will probably be found eventually in the Mississippi River.

The spotted and bantam sunfishes have become so rare in the northern parts of their ranges that they are no longer probable additions to the Mississippi River fauna.

The slough darter is common in many tributaries and adjacent swamps in southern Illinois but has not been taken in the river proper.

The cisco, *Coregonus artedii,* was reported from pool 8 (UMRCC 1953). Details are now lacking, but whatever the provenance of the specimen, if indeed it was correctly identified, the cisco does not occur naturally in the Mississippi River.

The cypress minnow, *Hybognathus hayi,* was reported from three sites below the mouth of the Missouri River (Smith 1965:7), but the specimens are here reidentified as juveniles of *H. nuchalis.*

THE CONTRIBUTIONS OF TRIBUTARIES

Of the 134 species recorded here, 30 probably represent stragglers that are accidental in the Mississippi River. *Salmo gairdneri* evidently came from trout-stream tributaries, and the following eight species probably cam

from marginal sloughs and lakes: *Umbra limi, Esox americanus, Notropis anogenus, Aphredoderus sayanus, Fundulus notti, Centrarchus macropterus, Lepomis microlophus,* and *Etheostoma exile.* The origins of the specimens of *Ictalurus catus* and *Ctenopharyngodon idella* are unknown. A long list of stragglers from tributary streams includes: *Dionda nubila, Nocomis biguttatus, Notropis boops, Notropis chrysocephalus, Notropis rubellus, Notropis venustus, Phoxinus erythrogaster, Semotilus atromaculatus, Semotilus margarita, Fundulus olivaceus, Culaea inconstans, Micropterus punctulatus, Etheostoma caeruleum, Etheostoma flabellare, Etheostoma spectabile, Etheostoma zonale, Percina maculata, Percina sciera,* and *Cottus carolinae.*

Six other species of small fishes, although never recorded from the Mississippi River, are common in some of the small tributaries and may eventually be found as stragglers in the river. They are the ribbon shiner, *Notropis fumeus*; telescope shiner, *Notropis telescopus*; bleeding shiner, *Notropis zonatus*; creek chubsucker, *Erimyzon oblongus*; slender madtom, *Noturus exilis*; and northern studfish, *Fundulus catenatus.*

The most dramatic contribution of a tributary to the regular fauna is made by the Missouri River, having introduced into the Mississippi the silt-tolerant *Scaphirhynchus albus, Hybognathus argyritis, Hybognathus placitus, Hybopsis gelida, Hybopsis gracilis,* and *Hybopsis meeki.* The Ohio River has a diluting effect upon the Mississippi's silty water. Near the mouth of the Ohio there is a sharp increase in the abundance of *Alosa chrysochloris, Dorosoma petenense, Notropis shumardi, Notropis volucellus,* and *Menidia audens.* Medium-sized rivers appear to contribute little or nothing to the river fauna and to have assemblages of typical Mississippi River fishes near their mouths.

PRESENT STATE OF THE MISSISSIPPI RIVER

Despite the steady decline in the number of commercial fishermen and despite highly publicized references to the Mississippi River as a sewer, the evidence available indicates that the Mississippi has a rich fish fauna and that it supports good populations of most of its native species. With the exception of the muskellunge, no indigenous species of fishes are known to have been extirpated in historic times.

Several species appear to be less generally distributed and less common than formerly, but their decline cannot be attributed with certainty to increased pollution. Species such as the lake sturgeon were said to be decimated in the Mississippi River 60 or more years ago (Forbes & Richardson 1908:25). It is probable that drainage of marginal lakes and sloughs, erection of flood-control dams, destruction or modification of habitats through efforts to maintain a navigable channel, and excessive siltation have been the major causes of the observable changes in the numbers and distribution of fishes. However, such current threats as pesticide residues, mercury accumulations, industrial and domestic wastes, oil spills, accidental discharge of toxicants, thermal pollution, the proposed creation of a 12-foot navigation channel, and loss of marginal refuges make the need for constant surveillance of the Mississippi River ever more acute.

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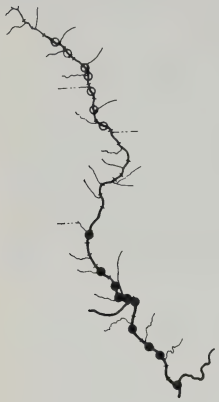
ICHTHYOMYZON CASTANEUS



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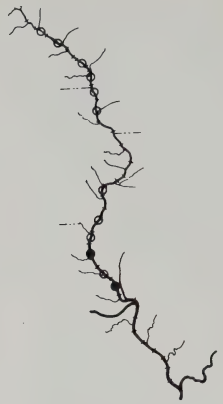

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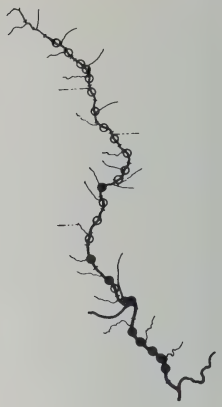

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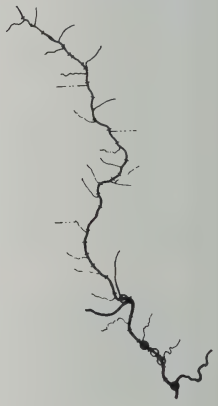
LEPISOSTEUS PLATOSTOMUS

LEPISOSTEUS SPATULA



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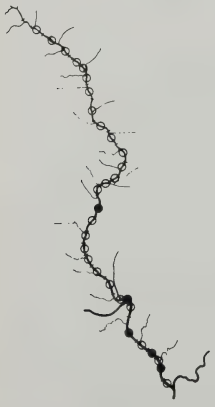

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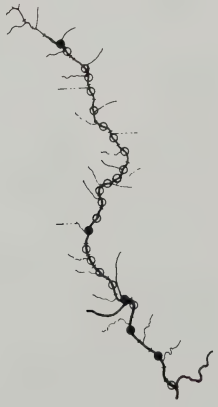

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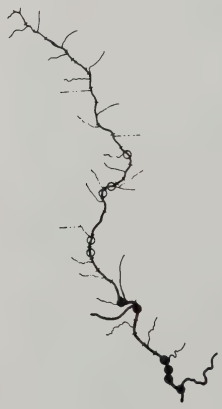
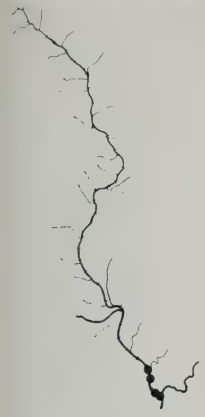


DOROSOMA CEPEDIANUM

DOROSOMA PETENENSE



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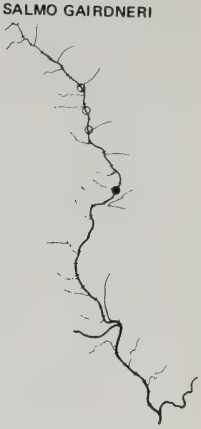

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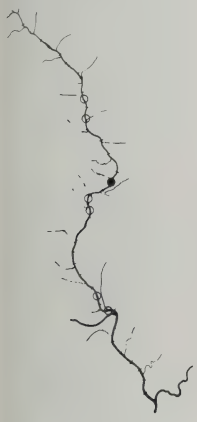

ESOX LUCIUS

CAMPOSTOMA ANOMALUM

CYPRINUS CARPIO

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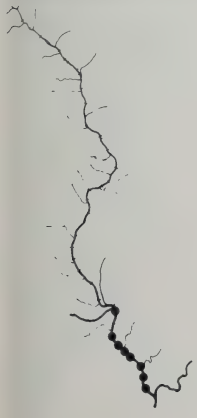

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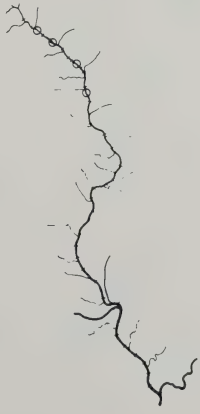

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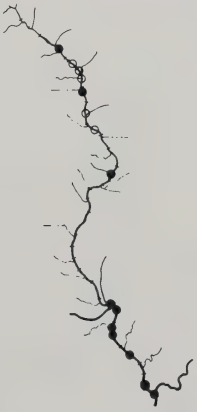

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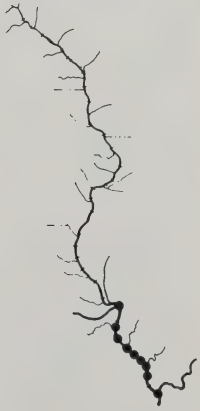

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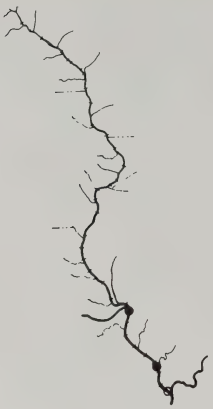
HYBOPSIS GELIDA



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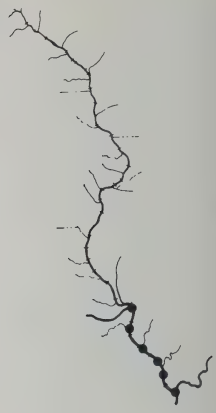
HYBOPSIS MEEKI



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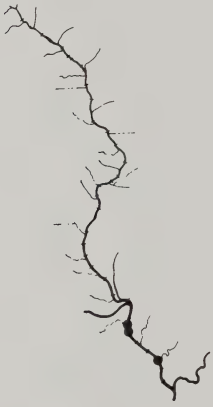
HYBOPSIS X-PUNCTATA



NOTEMIGONUS CRYSOLEUCAS

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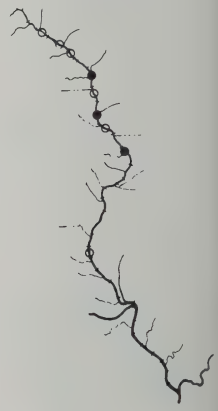

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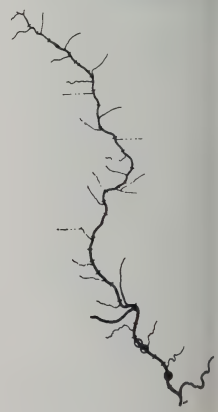

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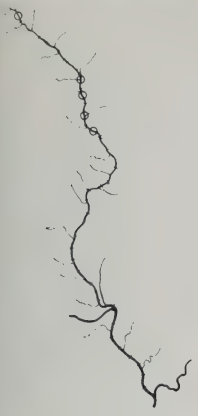

NOTROPIS DORSALIS

NOTROPIS EMILIAE

NOTROPIS HUDSONIUS

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NOTROPIS STRAMINEUS

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PIMEPHALES NOTATUS

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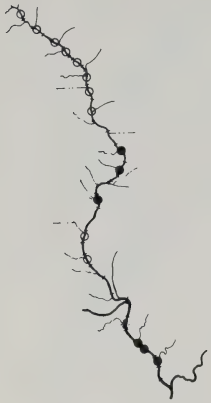

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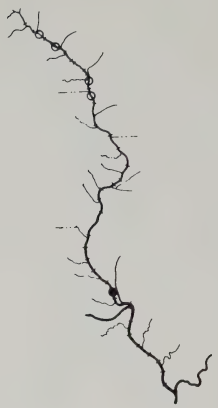

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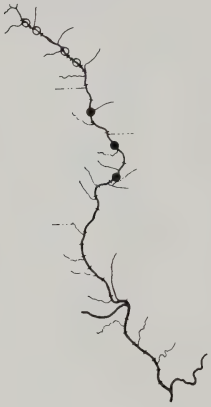

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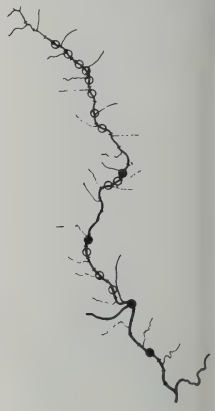

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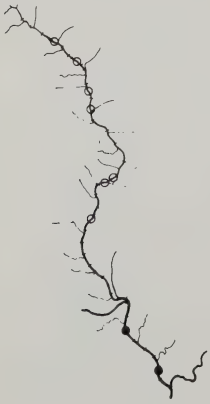

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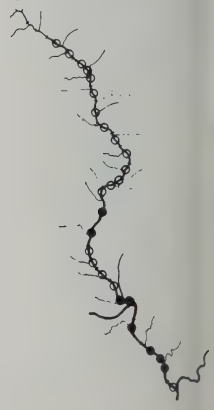

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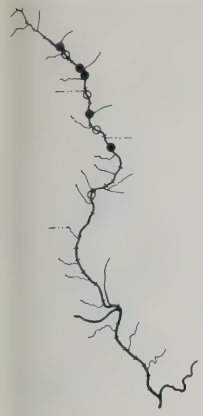

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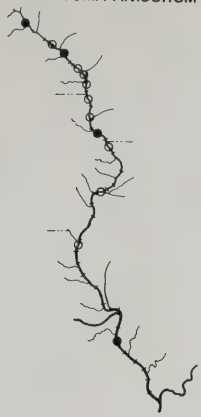

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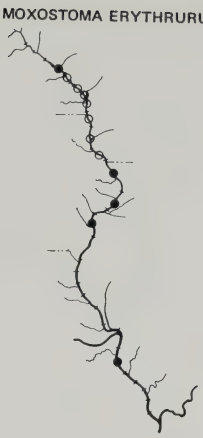

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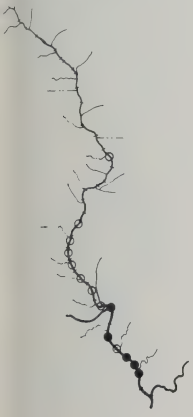

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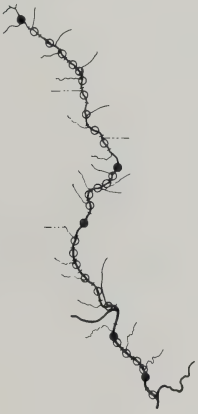

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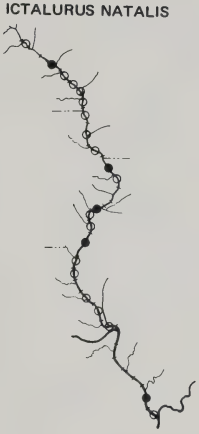

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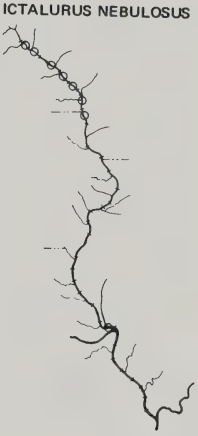

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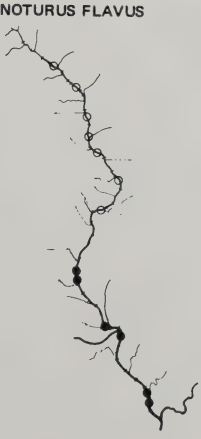

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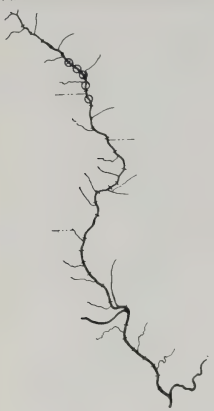

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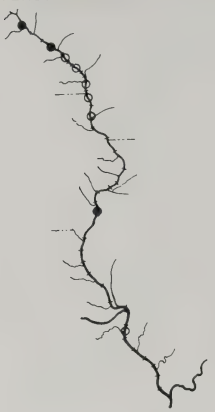

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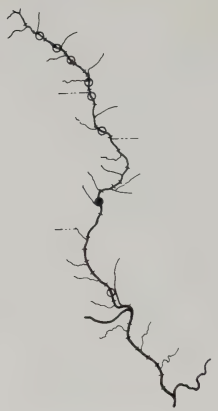

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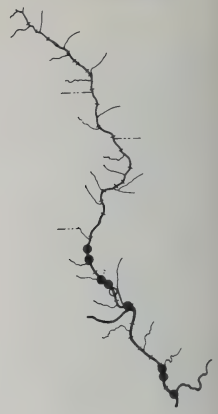

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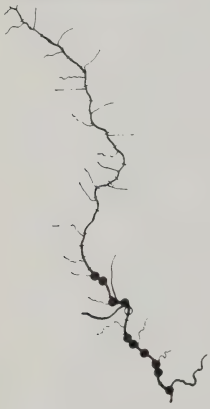

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MORONE CHRYSOPS

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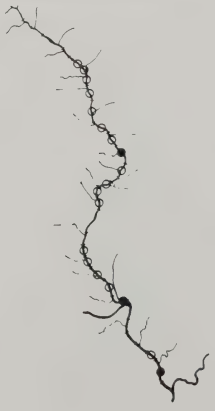
AMBLOPLITES RUPESTRIS

LEPOMIS GULOSUS



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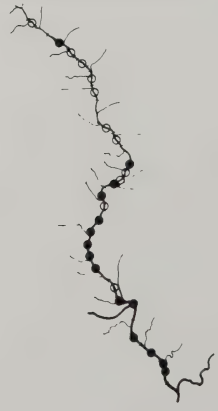

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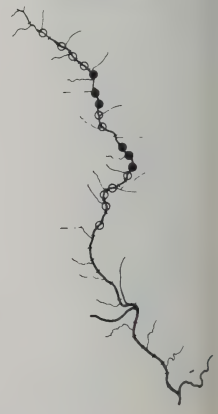

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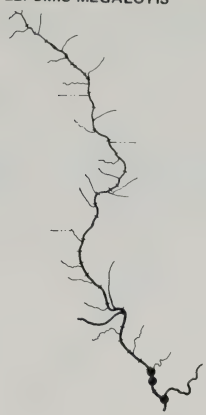

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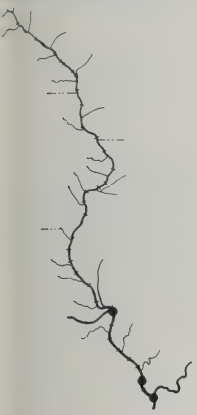
MICROPTERUS PUNCTULATUS



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POMOXIS NIGROMACULATUS

AMMOCRYPTA CLARA

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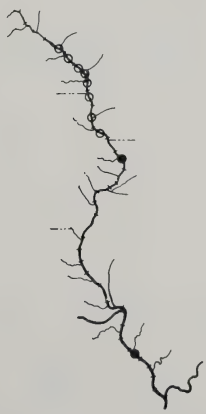

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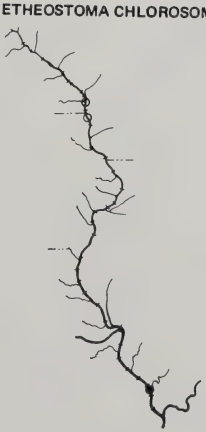

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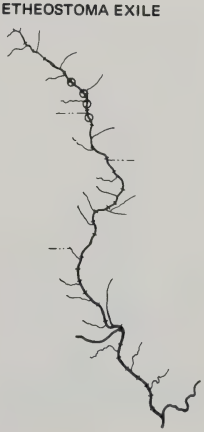

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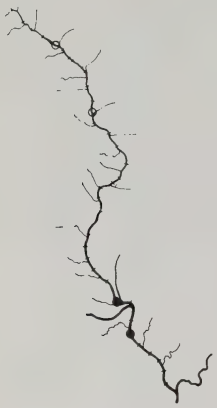

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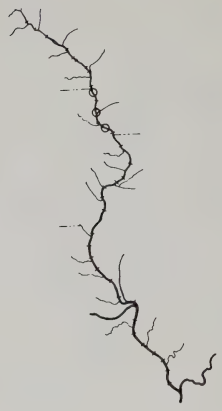

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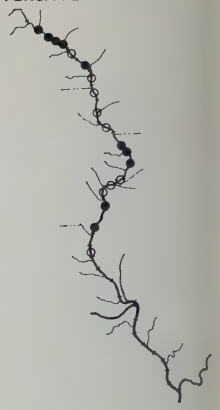

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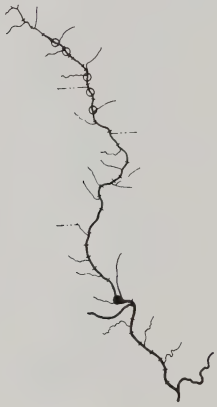
PERCINA MACULATA



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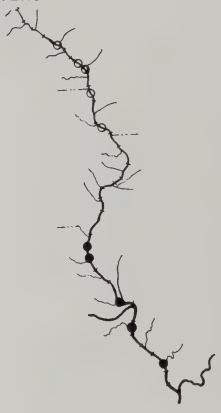

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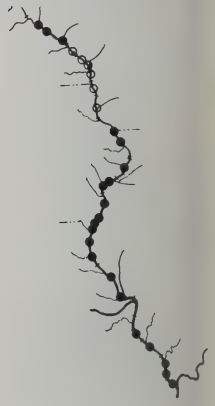


STIZOSTEDION CANADENSE

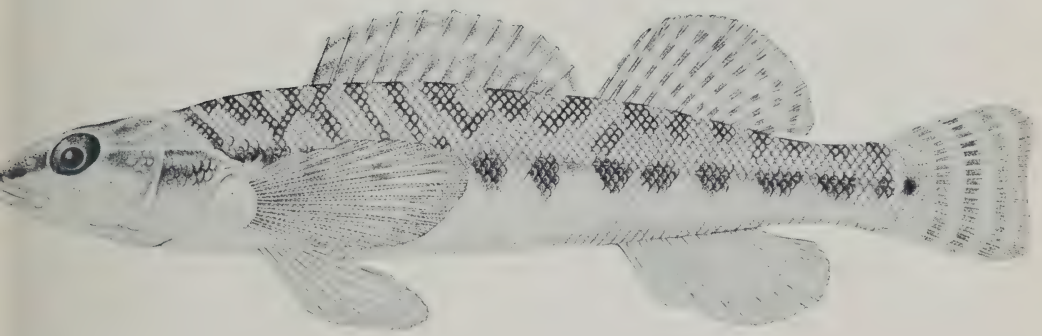
STIZOSTEDION VITREUM

APLODINOTUS GRUNNIENS

(29460—6M—5-71)

THE LIFE HISTORY OF THE SLENDERHEAD DARTER, *PERCINA PHOXOCEPHALA*, IN THE EMBARRAS RIVER, ILLINOIS

Lawrence M. Page
Philip W. Smith



LLINOIS NATURAL HISTORY SURVEY
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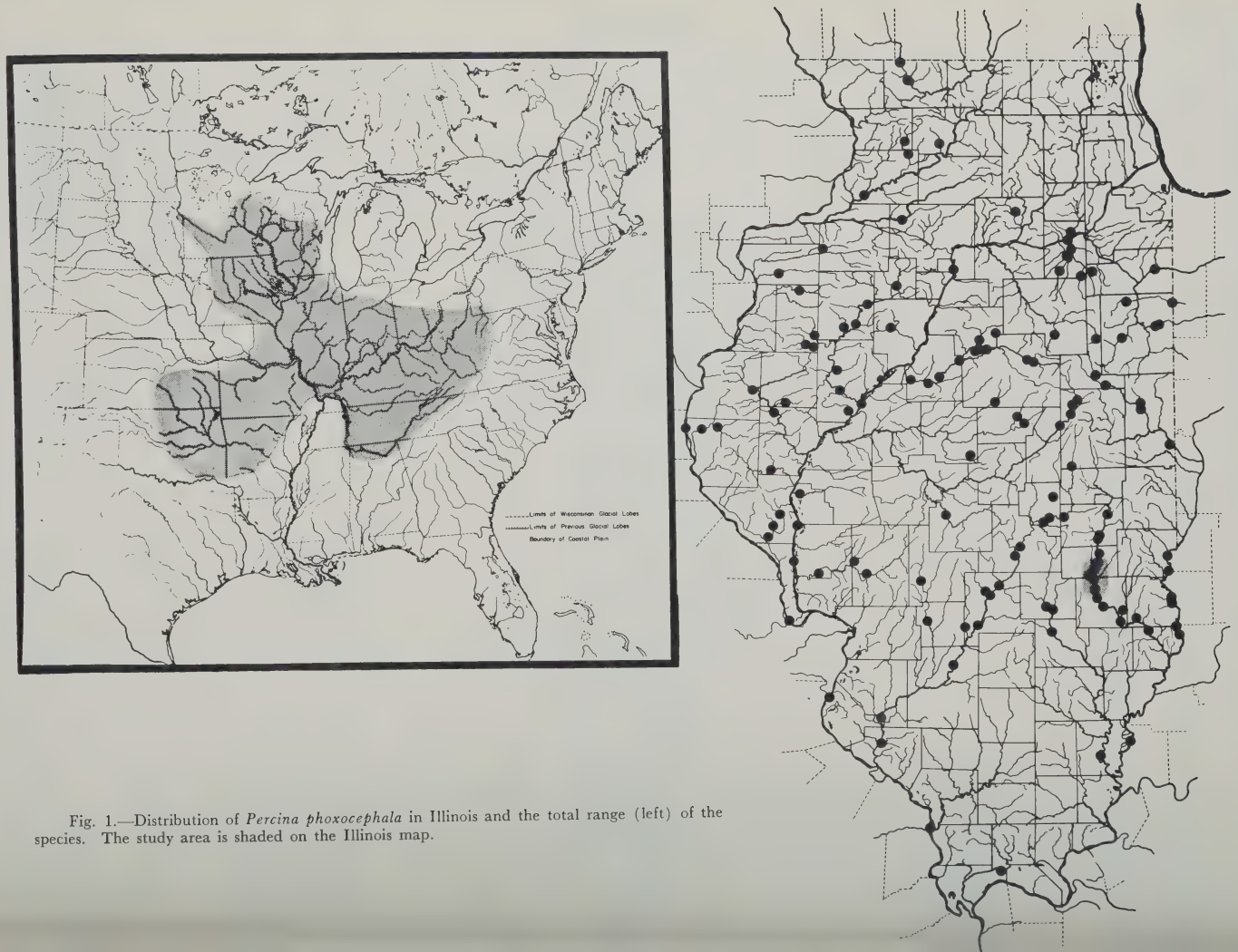

Fig. 1.—Distribution of *Percina phoxocephala* in Illinois and the total range (left) of the species. The study area is shaded on the Illinois map.

THE LIFE HISTORY OF THE SLENDERHEAD DARTER, *PERCINA PHOXOCEPHALA*, IN THE EMBARRAS RIVER, ILLINOIS

Lawrence M. Page and Philip W. Smith

THE SLENDERHEAD DARTER, *Percina phoxocephala* (Nelson), is the most widely distributed and best known of the four species assigned to the subgenus *Swainia*, which also includes *P. squamata* (Gilbert & Swain 1887), a species with a small range centered in eastern Tennessee; *P. oxyrhyncha* (Hubbs & Raney 1939), limited to West Virginia and Virgina; and *P. nasuta* (Bailey 1941), occurring in northern Arkansas, eastern Oklahoma, and southern Missouri.

Despite many references to the occurrence, relative abundance, and habitat preferences of *P. phoxocephala*, details of its life history are limited to observations made in Iowa by Karr (1963) and in Illinois by Thomas (1970). No published information is available on the life histories of the other species of *Swainia*. Because of the paucity of life-history data and the availability of a large population of *P. phoxocephala* in the middle Embarras River, a detailed study of the life history of this darter was commenced in August 1967 in conjunction with a similar study of the dusky darter, *P. sciera*. References to *P. sciera* in the following text are based on the latter investigation (Page & Smith 1970).

The slenderhead darter was described by Edward W. Nelson (1876:35) as *Etheostoma phoxocephalum* from "the Illinois [River] and its tributaries." The species (cover illustration) is a medium-sized darter, sexually mature individuals ranging from 40 to 80 mm in standard length, with a slender body and an attenuated snout. Its scales are small, the lateral-line count ranging from 60 to 80 scales. Opercles and nape are scaled; cheek squamation is variable. The breast of the female is naked, except for one or two enlarged, strongly ctenoid scales. The posterior half of the male's breast is scaled; the anterior half is naked. Dorsal spines number 11 or 12, soft dorsal rays 11–14. The anal fin has two spines and eight or nine soft rays. The gill covers are moderately conjoined.

The dorsum is light brown or straw color with darker brown vermiculations and blotches. The venter is white. Along each side of the body is a row of 10–16 rather obscure, more or less confluent, dark blotches. There is a small, discrete, black caudal spot and a dark stripe extending from the tip of the snout backward through the eye. Usually there is no suborbital bar. The best field character is the submarginal band of bright orange in the spinous dorsal fin.

The male can be distinguished from the female at all seasons and all sizes above 25 mm standard length by a median row of enlarged specialized scales extending from the midpelvic area to the anus. During late spring and early summer the male has closely spaced melanophores over the breast and belly and on the ventral fins; the female is white below and has only a few scattered melanophores on the anal fin. The spinous dorsal fin of the male is more heavily pigmented than is that of the female, the basal portion being quite dark. For a few weeks prior to spawning the female can be recognized by its distinctly enlarged genital papilla; the genital papilla of the male is a small triangular flap.

The small young of the species can be readily distinguished from other young darters in the Mississippi River valley by the combination of a slender habitus, attenuate snout, and the characteristic dorsal spotting.

P. phoxocephala occurs from western Pennsylvania to northeastern South Dakota—although it is for the most part absent from the Great Lakes drainage—and southward to northern Alabama and southern Oklahoma (Fig. 1). The species is not found in the lower Mississippi River valley and rarely occurs in low-gradient, lowland streams anywhere within its range. In Illinois it is widely distributed and generally common, except in the northeastern and extreme southern parts of the state.

We are much indebted to Raymond T. Schaaf, Mrs. Dorothy M. Smith, Norman D. Penny, Hartley F. Hutchins, Robert O. Watson, Miss C. Catherine Huheey, and the late Robert L. Hass for aid in collecting specimens; to our entomologist colleagues Donald W. Webb and Drs. John D. Unzicker and Milton W. Sanderson for their help in identifying arthropod remains in darter stomachs; to Dr. Marvin C. Meyer of the University of Maine for identifying the leech parasite found on our *P. phoxocephala* specimens; to Harman F. Smith, Illinois State Water Survey, for providing data on the water chemistry of the Embarras River; and to our associate Dr. R. Weldon Larimore for counsel on various matters. We also thank Chief Fishery Biologist A. C. Lopinot of the Illinois Department of Conservation and his staff of

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COVER ILLUSTRATION: Adult female *Percina phoxocephala* collected in May in the Embarras River, umberland County, Illinois. From a drawing by Mrs. Alice Ann Prickett.

biologists for a considerable number of Illinois collections of darters.

The drawings of *P. phoxocephala* and genital papillae were done by Mrs. Alice Ann Prickett, University of Illinois School of Life Sciences Artist. Assistance in preparing the illustrations was provided by Illinois Natural History Survey Technical Illustrator Richard M. Sheets and Survey Photographer Wilmer D. Zehr. The manuscript was edited by Robert M. Zewadski, Associate Technical Editor of the Survey. Dr. David A. Etnier, University of Tennessee, served as special guest reviewer.

THE STUDY AREA

The area selected for study (the shaded oval in the lower-right quarter of Illinois in Fig. 1) extends from a gravel bar in the middle Embarras River ½ mile north of Greenup, Cumberland County, south to a site 3 miles west of Rose Hill, Jasper County, Ill., although most of the collections were made over gravel bars at Greenup.

The Embarras River, a tributary of the Wabash River, flows through the Wisconsinan end moraines in the vicinity of Charleston and has deposited large quantities of glacial gravel and sand for the entire length of the study area. The water is well oxygenated by flowing over the many fast riffles bordering sand and gravel bars that alternate with deep, relatively quiet pools. Chemical measurements taken in the Embarras River at Camargo in Douglas County from October 1966 to April 1968 by the Illinois State Water Survey and made available through the courtesy of Mr. Harman F. Smith, indicated that water quality was unusually high and that pollution was minimal (Page & Smith 1970:5).

In the vicinity of the study area the stream could be classed as a small to medium-sized river. During low water stages the channel was only 15—30 feet wide and in riffle areas barely a foot in depth, although there were some deep pools at bridge sites and at abrupt bends in the river. During flood stages the inundated floodplain was almost 1 mile wide.

One of the principal study sites, 1 mile west of Greenup, had a variety of habitats, consisting of gravel bars and gravelly raceways, sandbars and sandy raceways, a rubble riffle, and several silt-bottomed pools.

Fig. 2.—Study area on the Embarras River ½ mile north of Greenup, Ill.

Another site, ½ mile north of Greenup, was similar but had more extensive stretches of gravel (Fig. 2).

METHODS

Minnow-seine collections were made at 2-week intervals from August to November 1967 and at irregular intervals throughout 1968, 1969, and 1970 as material was needed to obtain information for all seasons. A total of 45 collecting and observation trips was made to the study area between August 4, 1967 and September 10, 1970.

In the field notes were made on the river and weather conditions, pigmentation of the darters, and the habitats in which specimens were captured. During the spring and early summer months, water and air temperatures were routinely recorded.

Occasionally various habitats were sampled to determine habitat preferences, but most efforts were concentrated in the channels, where the species was most easily obtained. During the winter months numerous habitats were sampled in an effort to find the overwintering habitat of the species. Obtaining specimens during the winter and during periods of high water proved difficult, and no specimens were secured during January or December. Specimens collected during the 3-year study period were distributed as follows: February, 1; March, 1; April, 1; May, 35; June, 50; July, 19; August, 16; September, 75; October, 25; November, 15.

Supplemental specimens in the Illinois Natural History Survey ichthyological collection provided information to help fill the gaps resulting from the difficulty of collecting specimens during the cold months. A total of 440 preserved specimens was examined in the study. Only the 238 specimens collected and examined from the study area were used for the growth measurements, and only collections from the study area made during the study period were used in discussions of population characteristics.

Specimens were dropped into 10-percent formalin as soon as they were captured. Later they were measured, their age and sex were determined, and details of color pattern and the presence of external parasites were noted. Unless stated otherwise, all measurements given in the text are standard lengths. Age determinations were made by counting annuli on scales removed from just above the lateral line below the junction of the spinous and soft dorsal fins.

Some specimens from each collection were dissected and examined for stomach contents, the presence of macroscopic parasites in the alimentary canal, and gonad condition. Gonads were measured, and a few were blotted dry and weighed on a chain balance. Ovaries showed significant increases in weight as the spawning season approached, but testes were too small to be weighed accurately. Ova were counted in several females. The stomachs of some potential predators of *P. phoxocephala* were examined for darter remains.

Living *P. phoxocephala* specimens were brought to the laboratory several times during the study to observe their behavior in aquaria. When it became evident that aquarium-held captives were not going to spawn, eggs and sperm were stripped from ripe adults in several unsuccessful attempts to obtain embryos.

On October 17, 1967 a quantitative sample was taken ½ mile north of Greenup with an electric seine (Page & Smith 1970:5) to estimate the composition of the fish fauna at the site and the number of individuals per areal unit of habitat.

HABITAT AND ASSOCIATED SPECIES

In the Kaskaskia River of Illinois, Thomas (1970:7) found *P. phoxocephala* to be most abundant in the middle river, rare in the headwaters, and occasional in the lower river. The moderate-to-fast current over gravel and the high riffle-to-pool ratio in the middle river were considered responsible for the increased abundance in the middle river (ibid.:7, 16).

In Ohio, Trautman (1957:545) found *P. phoxocephala* to be most common over "extensive bars and riffles which contained clean sand and small gravel that was almost free of silt." In Kansas, the species occurs "in swiftly-flowing, shallow water, over a bottom of loose gravel or of bedrock littered by stones" (Cross 1967: 292). In the portion of the Embarras River used for both the *P. sciera* and the *P. phoxocephala* life-history studies, the two species were generally found occupying the same habitat, the relatively shallow, gravel-bottomed portion of the river channel. *P. phoxocephala* was somewhat less restricted to gravel than was *P. sciera* and occasionally was taken in the channel over sand.

Collections from elsewhere in Illinois have revealed more plasticity by *P. phoxocephala* in habitat choice than was exhibited by the population in the Embarras River. Specimens have been taken from small-stream riffles, large rocky riffles, and even sandy pools of large rivers. However, the abundance of *P. phoxocephala* in the middle Embarras River indicates the optimal habitat for the species to be the gravel-bottomed raceways of medium-sized rivers with moderate current.

Juvenile *P. phoxocephala* remained in the spawning habitat (shallow riffles along gravel bars) several weeks after hatching. At approximately 1 month of age the young darters moved out into the deeper water of the channel.

Page & Smith (1970:6) summarized the species diversity in a section of the Embarras River blocked off with minnow seines and sampled with an electroseine. They found *P. phoxocephala* to be the second most common darter and the 13th most common species of fish; it constituted 0.5 percent of the total fish population. Collections taken in the other study areas over a 3-year period tend to substantiate this numerical relationship between *P. phoxocephala* and associated species.

The species most commonly associated with *P. phoxo-*

cephala were *Notropis whipplei, N. spilopterus, N. stramineus, Pimephales vigilax, Ericymba buccata, Percina sciera, Hypentelium nigricans, Micropterus punctulatus,* and *Phenacobius mirabilis.*

REPRODUCTION

The Reproductive Cycle of the Male

Males were sexually mature and ready to spawn during the first spring following their hatching. The smallest male captured in spring was a 40-mm specimen collected on May 27, 1969; although breeding pigmentation was absent in this fish, its testes were large (6 x 1.5 mm) and it apparently was capable of spawning, as were all of the larger males collected in the spring and examined for sexual maturity.

The larger the male, the earlier the breeding pigmentation began to develop and the more intense it became by spawning time. Males 2 years old collected on May 27, 1969 were considerably darker than females and somewhat darker than 1-year-old males collected at the same time. The brown vermiculations on the dorsum were darkened in males, and in contrast to females, the breast; belly; underside of the head; and membranes of the anal, soft dorsal, and pelvic fins of the males were covered with many expanded melanophores, giving them an over-all dusky appearance (Fig. 3).

Besides the duskiness of the males, there was a pronounced color difference between the sexes in the pigmentation of the soft dorsal fin. In addition to increased melanization, the dorsal rays of males were boldly outlined with yellow; the soft dorsal fins of the females had no visible yellow pigment.

Although the width and color intensity of the yellow-orange submarginal band in the spinous dorsal fin were usually greatest in males, pronounced variations occurred in both sexes. The color varied from pale yellow to bright orange.

Pigmentation changes began in April and peaked at spawning time. The darker color of freshly captured, large males taken in the spring made them easily separable from females. Large size and more intense coloration undoubtedly enhanced sex recognition and provided older males an advantage over younger males in attracting females.

Breeding *P. phoxocephala* males did not develop tubercles. Collette (1965:577) found breeding tubercles on none of the species of *Swainia.* The genital papillae of males were small, triangular flaps which enlarged slightly as spawning neared (Fig. 4).

The testes began enlarging in late summer, and continued to enlarge until spawning time. In specimens collected on September 21, the length of the testes averaged 10 percent of the standard length; in a specimen

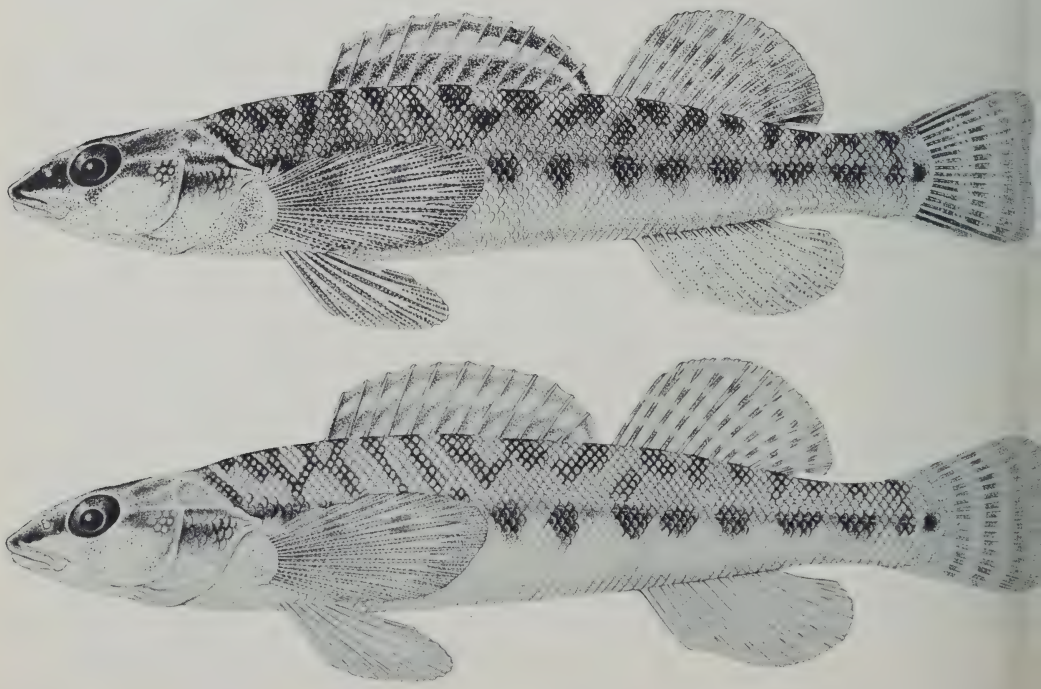

Fig. 3.—Pigmentation patterns of a 63-mm breeding male (top) and a 56-mm breeding female (bottom) *Percina phoxocephala,* both captured on May 26, 1970.

collected on October 14, 11 percent; on April 28, 19 percent; on May 27, 15 percent; and on June 8, 21 percent.

The Reproductive Cycle of the Female

No difference between the pigmentation of breeding females (Fig. 3) and that of non-breeding females was discernible. Sexual dimorphism in *P. phoxocephala* seems to be limited to the contrast between the "normal" pigmentation of *P. phoxocephala* and the pigmentation of breeding males, the difference in breast squamation, and the presence of the specialized scales on the mid-belly of males versus their absence on females.

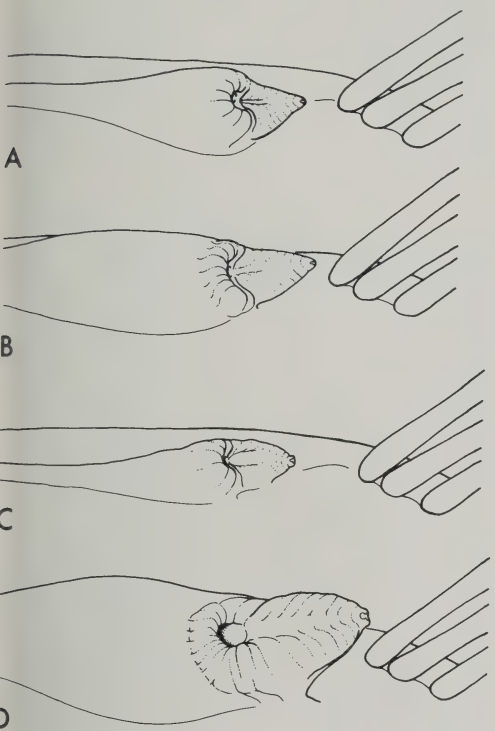

Fig. 4.—Urogenital papillae of: *A*, male in the fall; *B*, male in the spring; *C*, female in the fall; and *D*, female in the spring.

In the spring the genital papillae of females were enlarged, striated, conical structures (Fig. 4). In the fall the papillae of females were morphologically similar but proportionally much smaller than those of specimens taken in the spring.

Females having attained a standard length of at least 42 mm were sexually mature at 1 year of age. All spring-captured females examined that were 42 mm or larger contained ova at least 1 mm in diameter and were ready to spawn. The only sexually immature spring-collected female was a 38-mm specimen collected on May 27, 1969.

The prespawning period was characterized by the differentiation and maturation of ova; the spawning act by the release of mature eggs; and the postspawning period by the absorption of the remaining ova and recovery of the ovaries. In *P. phoxocephala,* the recovery time for females was very short, and enlargement of the ovaries began soon after spawning (Table 1).

Early stages of ova maturation proceeded slowly, but as spawning time approached, development was rapid. The growth of ova was reflected in an increase in the weight of the ovaries, which, in relation to body weight, showed an exponential increase between July and the following June (Fig. 5).

As with other fishes, developing ova were easily categorized into three groups based on size and color: the smallest ova were white and less than 0.5 mm in diameter; the intermediate were between 0.6 and 1.0 mm and yellow; and the largest were 1.1–1.3 mm and yellow to orange in color.

Ova categorized as intermediate were present in a February-collected female (Table 2); large ova first appeared in April. The proportion of small ova decreased as spring approached, and the proportion of large ova increased. The number of intermediate ova

Table 1.—Lengths and weights of ovaries of *Percina phoxocephala* collected in different months of the year.

Collection Date	Length in mm			Weight in Grams		
	Standard Length of Female	Length of Ovary	Ovary Length as Percent of Standard Length	Adjusted Weight[a] of Female	Weight of Both Ovaries	Ovary Weight as Percent of Adjusted Weight
uly 21, 1959	67	13	19.4	3.66	0.02	0.5
ugust 23, 1967	55	9	16.4	2.08	0.02	1.0
eptember 1, 1967	54	8	14.8	1.82	0.02	1.1
ctober 22, 1967	57	11	19.3	2.39	0.06	2.5
ovember 8, 1963	66	14	21.2	3.02	0.09	3.0
ebruary 23, 1969	58	13	22.4	2.40	0.12	5.0
pril 28, 1968	44	12	27.3	1.00	0.12	12.0
lay 27, 1969	56	14	25.0	2.30	0.35	15.2
une 8, 1969	60	18	30.0	2.59	0.52	20.1

[a] Adjusted weight is the weight of the female minus the ovaries, stomach, and intestines.

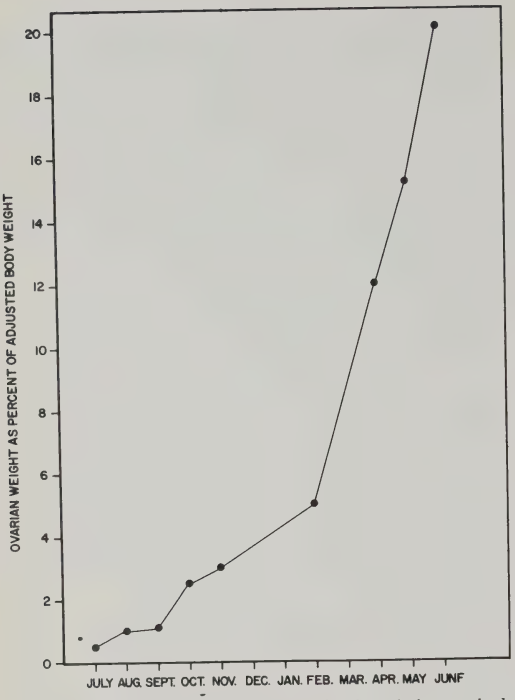

Fig. 5.—Increase in weight of ovaries in relation to body weight from the end of one spawning season to the beginning of the next.

remained between 9 and 24 percent in specimens collected after late February.

Between 500 and 2,000 ova were produced by each female in one season, but only about 10—50 percent reached mature size. If we assume that darters lay all the mature eggs, as suggested by Fahy (1954:166) and Winn (1958*b*:181), each female *P. phoxocephala* lays from 50 to 1,000 eggs in one season. The largest number of mature ova actually counted was 720 in a 60-mm female; the smallest number was 50 in a 45-mm female. Karr (1963:235) counted the eggs in six *P. phoxocephala* from Iowa and found a range of 186—365. Large females produced more eggs than did small females. The mean number of mature eggs in three spring-collected 1-year-old females examined during this study was 83; the mean number in six spring-collected 2-year-olds was 270.

Mature eggs stripped from ripe females were transparent and adhesive, averaged 1.3 mm in diameter, and contained one large oil droplet.

Spawning

The peak spawning period in 1969 was June 7—14, and in 1970, June 5—12. In 1968 high water prevented spring collections and presumably delayed spawning,

Table 2.—Differentiation and growth of ova in *Percina phoxocephala* collected in the study area.

Collection Date	Estimated Percent of Differentiated Ova	Percent of Differentiated Ova by Size Group		
		0.1-0.5 mm	0.6-1.0 mm	1.1-1.3 mm
October 3, 1967	30	100	0	0
November 17, 1963	40	100	0	0
February 23, 1969	80	81	19	0
April 28, 1968	over 90	75	17	8
April 28, 1968	over 90	80	9	11
May 4, 1968	over 90	69	16	15
May 27, 1969	over 90	59	24	17
June 8, 1969	over 90	56	23	21
July 18, 1967	over 90	42	17	41

inasmuch as the spawning habitat (shallow gravel riffles) was not available until sometime in July.

The spawning period for *P. phoxocephala* in central Illinois varies with climatic conditions and presumably may peak anytime after late May. Females heavy with mature eggs were captured at Greenup in late May in both 1969 and 1970, indicating that spawning could occur that early in the year under ideal conditions. Thomas (1970:8) collected ripe females in early August in the Kaskaskia River at about the same latitude as that of the Embarras River study area. He noted, however, that no ripe males were collected that late in the year, and it is highly improbable that spawning would occur later than early July in central Illinois.

The spawning habitat of *P. phoxocephala* is swift-flowing water 15—60 cm (½—2 feet) deep over gravel. Males move in mass into the spawning habitat well before the females do and presumably establish territories although no actual observations of territoriality were made. In 1970 males were common in the shallow water along gravel bars as early as May 29. The ratio of males to females captured in the shallow water on this date was 15:1; on June 5 it was 11:2. The fish spawned during the following week and by June 13 all adult *P. phoxocephala* had left the spawning grounds.

Spawning could neither be observed in the field nor induced in aquaria. The morphology and spawning habitat of *P. phoxocephala* suggest, however, that mating and deposition of the eggs occur in a manner similar to that described for other *Percina* species (New 1966; Loos & Woolcott 1969; Reighard 1913; Winn 1953, 1958*a*, and 1958*b*).

Juveniles remain in the spawning habitat 2—4 weeks after hatching. Several young were collected in the shallow water (15—30 cm deep) along a gravel bar in the study area where spawning was known to have occurred 2 weeks before. With the young *P. phoxocephala* (ranging from 19 to 27 mm) in the riffles were two young *P. sciera* (19 and 21 mm) and one young *P. caprodes* (33 mm). Collecting in the shallow riffle areas 2 weeks later produced no young *P. phoxocephala*.

DEVELOPMENT AND GROWTH

Development

The smallest specimen available (18.7 mm standard length, 22.4 mm total length) was collected in the study area on June 23, 1970. Presumably a product of the peak spawning period of June 5–12, the fish was estimated to be 2 weeks old. Its body proportions (Fig. 6) were essentially those of the adult, except that the head and eyes were large in relation to the size of the body. The head length was 32 percent of the standard length versus an average of 27 percent of the standard length for 10 adults. Squamation was nearly complete; the only areas lacking scales were the cheeks, opercles, nape, and the anterior two-thirds of the belly.

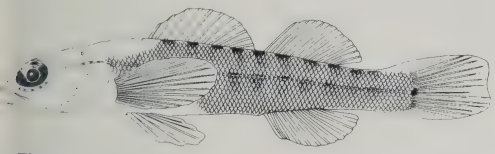

Fig. 6.—Two-week-old *Percina phoxocephala* 19 mm in standard length.

The pigmentation of this small specimen was weak but showed the pattern characteristic of adults. The dorsal spots, lateral blotches, band around the snout, and spots in the fins of adults were represented by concentrations of melanophores. Yellow pigment in the spinous dorsal fin indicated the beginning of the orange-yellow band characteristic of the adult *P. phoxocephala*. The lateral line was complete and fully pored. The head canals were nearly complete except for a wide medial interruption in the supratemporal canal.

Slightly larger specimens (21–23 mm) were almost identical in morphology to the smallest specimen although some had incomplete lateral lines. The specialized midventer scales were discernible on males at about 23 mm, and the orange band was present in the spinous dorsal fins of 25-mm specimens. At 27 and 28 mm, males were lacking only on the nape, and most individuals had completed supratemporal canals. Scales were not present on the nape until specimens reached a standard length of 33 mm.

The pigmentation of *P. phoxocephala* continued to darken throughout life. Older individuals in any particular collection always were slightly darker than the younger ones.

Growth

Standard length frequencies of specimens of *P. phoxocephala* taken from the study area indicated that rapid growth occurred during the first few months of life and the growth rate diminished with age. The growth curve of samples taken from the study area (Fig. 7) showed a continuous average increase in size except during October and November, when the mean standard lengths of two samples averaged less than those of the September sample. This autumn reversal, which also occurred in the study of *P. sciera*, is assumed to be the result of an emigration of the larger fishes from the comparatively shallow raceways (most efficiently sampled) to the deeper channel as winter approached.

Inasmuch as the average size of 12-month-old *P. phoxocephala* specimens was 46 mm, the young fish attained half of their 1st year's growth in about 2 weeks. *Etheostoma gracile* "attained almost half of their 1st year's growth in about 1 week" (Braasch & Smith 1967: 9). The growth rate of the Embarras River *P. phoxocephala* population was faster than that found for the Kaskaskia River population (Thomas 1970:14) and much more rapid than that of the population in Boone County, Iowa (Karr 1963:232). At the end of 1 year's growth, the Embarras River population averaged 45.7 mm in standard length; the Kaskaskia River population averaged 45.3 mm in total length; and the Iowa population averaged 34.1 mm in total length.

There is little indication of sex influence on size.

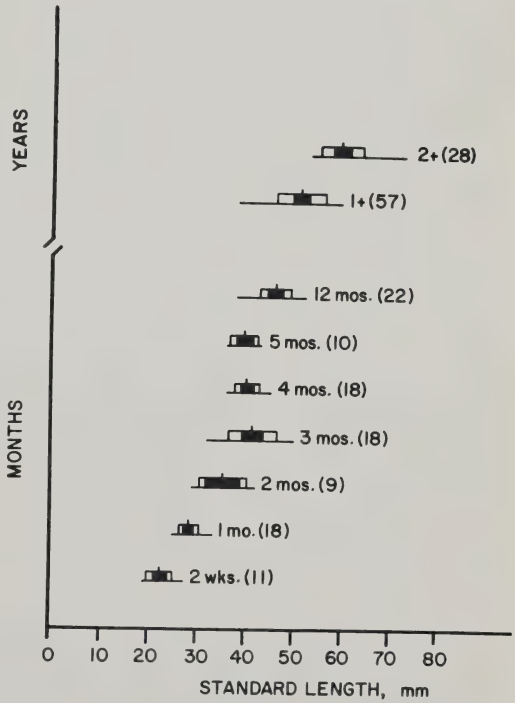

Fig. 7.—Growth of *Percina phoxocephala* in millimeters of standard length. For each sample the horizontal line represents range; the vertical line, mean; the hollow rectangle, one standard deviation to either side of the mean; and the black rectangle, two standard errors to either side of the mean. Numbers in parentheses are specimens measured. Samples of 1- and 2-year-old fish included Embarras River specimens from outside the study area.

Although the largest specimens collected in the study area were males, the differences between male and female mean standard lengths at various ages were not statistically significant. Thomas (1970:13) also found no influence of sex on growth rate.

DEMOGRAPHY

Density

Four specimens of *P. phoxocephala* were taken in the 507 square yards of river quantitatively sampled by an electric seine as described earlier. The sample contained 750 fishes, an average of 1.48 fish per square yard (average depth 30 cm) and one *P. phoxocephala* per 169 square yards. Assuming that, rather than being uniformly distributed in the area sampled, *P. phoxocephala* mainly occupied the gravelly raceway that constituted about one-fourth (127 square yards) of the area, a more realistic figure of one darter per 42.3 square yards of gravel habitat results. Because of the inefficiency of sampling by the electric seine and previous collecting in the area, the figure of one darter per 42.3 square yards may be rather low.

At two sites in the Kaskaskia River, Thomas (1970: 6) found more than 200 *P. phoxocephala* individuals per acre of water, which is one darter for approximately 24 square yards of water, almost twice the density of *P. phoxocephala* in the Embarras River. However, at many other sites in the Kaskaskia River, the number of *P. phoxocephala* individuals per acre was smaller than that in the Embarras River study area.

Composition

Of the 238 *P. phoxocephala* collected in the study area, 176 (74 percent) were young-of-the-year, 59 (25 percent) were 1-year-old fish, and 3 (1 percent) were 2-year-old fish (Table 3). No specimens 3 years old or older were examined, and in view of the sharp decrease in numbers in each successive age class, it is doubtful that in the Embarras River many individuals live to 3 or more years of age. Of 25 specimens from Boone County, Iowa, examined by Karr (1963:232), five were 3 years and two were 4 years old.

Table 3.—Distribution of sexes and year classes in *Percina phoxocephala* taken from the study area between August 4, 1967 and September 20, 1970.

Sex	Number by Year Class			Total
	—1	1+	2+	
Males	98	38	3	139
Females	72	21	0	93
Too small to sex	6	..	..	6
Total	*176*	*59*	*3*	*238*

Considerably more males than females were collected, giving a sex ratio of 1.5 males to 1 female. The sex ratio of the 170 young large enough to be sexed was also skewed in favor of the males, although less than that of the total sample (1.4:1). In the small sample from the Kaskaskia River that Thomas (1970:14) used to illustrate growth rate, there were 23 males and 18 females (1.3:1). However, much larger samples are needed to determine the true sex ratio of these populations.

Although the data in Table 3 suggest that *P. phoxocephala* males live somewhat longer than females, 12 of the 28 two-year-old fish examined for the data shown in Fig. 7 were females. If there actually is a skewed sex ratio in the population, more males than females would be expected in any age class, and this factor would obscure any sex influence on longevity.

The largest specimen examined by us was a 78-mm, 2-year-old male collected in the Kaskaskia River on September 6, 1968. Trautman (1957:543) listed the largest Ohio specimen as 4 inches long (approximately 100 mm total length).

Migration

P. phoxocephala exhibited the same annual migratory pattern as that shown by *P. sciera*, i.e., a late fall emigration from and an early spring return to the gravelly raceways (Fig. 8). Unfortunately, the habitat to which the darters emigrated in winter could not be determined. Quiet regions of the river, such as sluggish backwater areas and pools and the deeper portions of

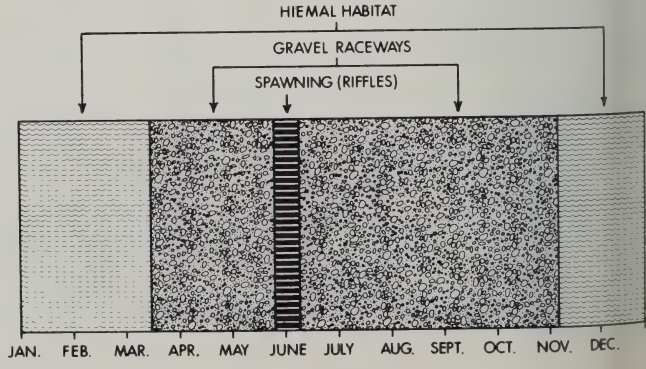

Fig. 8.—The habitats in the Embarras River occupied by *P. phoxocephala* throughout the year. The principal habitat, the gravel raceway, is abandoned during the spawning period and during the colder months of the year.

the channel, were seined, but no darters were found. In February a specimen was collected in the relatively shallow portion of the channel, but its occurrence there was exceptional, and other attempts to collect specimens in the winter months were unsuccessful. *P. phoxocephala* left the raceway areas in November and returned in March or April.

Besides the hiemal migration, the spring movements into and out of the spawning area involved a large proportion of the population and should be recognized as a breeding migration characteristic of the species. Whether *P. phoxocephala* migrated in and out of tributaries with the change in seasons as *P. sciera* was thought to do is unknown.

Territoriality

Mass movements of the males into the spawning habitat well before the females suggested that the species was territorial during the spawning season. Aquaria used to observe *P. phoxocephala* were probably too small to allow the establishment of territories although males were rather consistently belligerent toward other males.

PHYLOGENETIC RELATIONSHIPS

In his description of *Hadropterus nasutus*, Bailey (1941:1–2) suggested a close relationship with *P. phoxocephala* and *P. oxyrhyncha*. *Percina squamata*, the fourth species in the subgenus *Swainia*, is more generalized and less closely related, but it strongly resembles *P. phoxocephala* in some characteristics, most notably the pigmentation pattern.

Swainia is one of the most primitive subgenera of *Percina*. Generalized characteristics of the subgenus include the modest specialization of the midventral row of scales in the male, lack of pronounced sexual dimorphism, highly pelagic habits, and high meristic counts. Comparisons of data collected during this study and during the life-history study of *P. sciera* indicate *Swainia* to be somewhat less evolutionarily advanced than the subgenus *Hadropterus*.

Winn (1958*b*:188) suggested the degree of abatement of the gas bladder to be an indicator of phylogenetic advancement of darters. Page & Smith (1970:11) found *P. sciera* to have a large bladder, averaging approximately 16 percent of the standard length of the fish examined. In eight *P. phoxocephala* specimens the bladder was also large, ranging from 11 to 18 percent and averaging 15 percent of the standard length.

DIET AND FEEDING HABITS

Thomas (1970:8–12) examined the stomach contents of 103 *P. phoxocephala* from the Kaskaskia River, Illinois. He found the predominant food items to be "baetid nymphs, chironomid larvae, and hydropsychid larvae," and noted that certain organisms (e.g., stonefly naiads and elmid beetle adults), although abundant in the darter habitat, were avoided as food items by all four darters he studied. The young fed mainly on midge larvae.

In 45 specimens of *P. phoxocephala* from the Embarras River study area examined for stomach contents (Table 4), midge larvae and pupae, black fly larvae, caddisfly larvae, and mayfly naiads formed over 99 percent of the food items encountered. Less frequent items were amphipods, fish eggs, and terrestrial insects.

The small variety of food items found in *P. phoxocephala* was also found in *P. sciera* studied in the same area. In addition to a similarity in over-all diet, the seasonal variations in the diets of the two species were approximately concurrent; dipterans and mayflies predominated during all seasons, and caddisflies formed a large portion of the diet during the summer (Fig. 9). The correlation between the two fish species in seasonal variations in diet strongly suggests that both fed on whatever insect immatures were available and palatable,

TABLE 4.—Stomach contents of *Percina phoxocephala* of all sizes collected in the Embarras River. Figures in parentheses are numbers of stomachs examined.

	Percent of Stomachs Examined in Which Each Food Organism Occurred									
Food Organism	Feb. (1)	Mar. (2)	Apr. (4)	May (4)	June (9)	July (9)	Aug. (4)	Sept. (4)	Oct. (4)	Nov. (4)
idge larvae, pupae	100	100	25	50	44.4	55.6	50	100	75	50
ack fly larvae	100	...	100	25	22.2	22.2	..	25	..	..
addisfly larvae	100	...	25	25	22.2	44.4	25	50	50	..
ayfly naiads	...	...	75	100	66.7	66.7	..	50	25	50
iscellaneous	...	...	...	25	....	....	25	..	..	25

	Mean Number of Food Organisms Per Stomach									
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
idge larvae, pupae	5.00	3.00	0.25	2.75	1.89	3.33	1.00	15.75	3.25	0.75
ack fly larvae	1.00	....	15.50	15.50	6.00	0.44	....	0.50	....	....
addisfly larvae	1.00	....	0.25	0.25	0.44	2.33	0.25	1.50	1.75	....
ayfly naiads	....	....	1.25	2.75	4.33	1.00	....	0.50	2.50	0.75
iscellaneous	....	....	....	0.25	....	....	0.25	....	....	0.25

and that the variation was mainly an expression of cycles in insect populations.

The heaviest feeding occurred in May as the spawning season approached. The periods of least feeding activity were in the months following spawning (July and August) and in the colder months (November, February, and March).

As the darters increased in size, the over-all diet

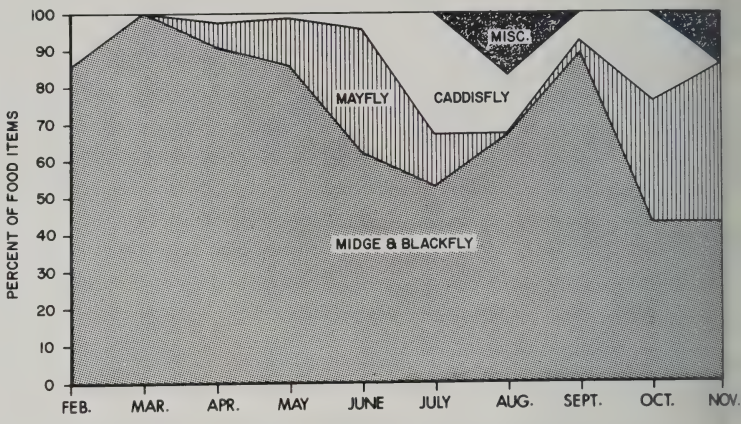

Fig. 9.—Seasonal variation in the diet of *Percina phoxocephala* specimens of all sizes. The percentage of each food item represents its contribution to the total number of items found in all fish examined each month.

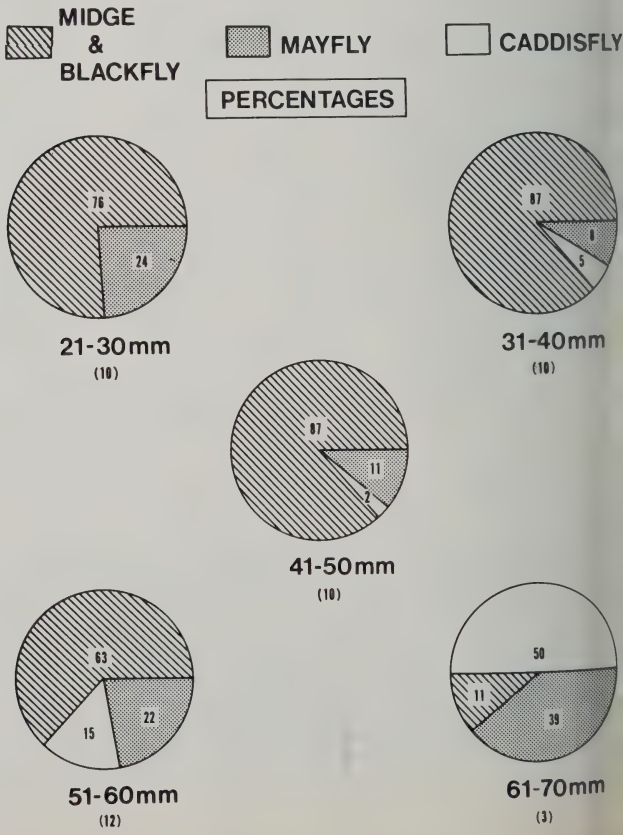

Fig. 10.—Composition of the diets of five size-classes of *Percina phoxocephala*. Numbers in parentheses are specimens examined.

omposition progressed from one dominated by dipteran arvae to include substantially greater portions of the arger mayfly and caddisfly immatures (Fig. 10). The mallest specimen (19 mm) available for dissection conained one mayfly naiad. Aquarium-held darters fed eadily on a variety of foods, including fish and shrimp lesh, earthworms, snails, isopods, and tadpoles of *Pseudcris triseriata*.

Some geographic variation in diet is to be expected, lthough other reports on the food of *P. phoxocephala* ave indicated basically the same composition. In a tudy conducted in Iowa, Karr (1963:234) found mayies to be the most common food organisms, with diptern and caddisfly larvae constituting the remainder of ne diet. Additional items encountered include dragony naiads and water boatmen (Forbes 1880:23; Forbes Richardson 1920:286; Cross 1967:293).

INTERACTIONS WITH OTHER ORGANISMS

ompetition

Observations of *P. phoxocephala* and *P. sciera* for 3 ears revealed no overt competition between them or ith any other coinhabitants. However, covert competion among species is more difficult to discern, and in eld studies can only be suggested in terms of similarities life histories and niche requirements. *P. sciera* and *phoxocephala* share certain ecological characteristics .g., similar diets, habitats, breeding habitats) in the mbarras River, and competition between them (and erhaps with other species) may intensify to the point population limitation in certain seasons of the year. or example, food may become limiting in winter.

edation

No evidence of predation on *P. phoxocephala* was und in the study area. Concurrent with the life-history udies of the darters, an investigation was conducted the feeding habits of the most abundant large predator in the river, *Micropterus punctulatus* (Smith & Page 1969). The only darter remains encountered as food items were those of *Etheostoma nigrum*. Thomas (1970: 16) also found no evidence of predation on *P. phoxocephala*.

Parasitism

During the summer and fall, adult and young darters were often parasitized by a small leech, identified by Dr. Marvin C. Meyer as *Piscicolaria reducta* Meyer (Piscicolidae). Darters with leeches attached were collected from late June into November; more than half of those collected in October and November were parasitized by one to eight leeches of various sizes. Attachment was usually to the caudal fin, sometimes to the caudal peduncle or a pectoral fin. In some cases fin rays showed slight damage.

Of 45 *P. phoxocephala* individuals dissected for food analysis, one had one small nematode in its intestines, and another had three nematodes. Another darter of this species from Henry County, Ill., had two small acanthocephalans in its intestines.

Hybridization

The only literature report known to us of natural hybridization involving *P. phoxocephala* is that by Thomas (1970:16) on two specimens of *Percina maculata* x *P. phoxocephala* hybrids from the Kaskaskia River at Sullivan, Ill.

SUMMARY OF LIFE-HISTORY DATA ON P. PHOXOCEPHALA AND P. SCIERA

A comparison of the life histories of *P. phoxocephala* and *P. sciera* reveals a few ecological and demographic differences and many similarities (Table 5). The differences reflect divergent specialization. The similarities are due, in part, to the relatively close relationship between the two darters and to the fact that both species were investigated in the same study area.

TABLE 5.—Summary of life-history information on Embarras River populations of *Percina phoxocephala* and *P. sciera*.[a]

Characteristic	*P. phoxocephala*	*P. sciera*
incipal habitat	Gravel raceways of moderate-sized rivers	Gravel raceways of moderate-sized rivers
awning habitat	Gravel riffles 15–60 cm deep	Gravel riffles 30–90 cm deep
abitat of juveniles	Gravel riffles	Gravel riffles
e at reaching sexual maturity	1 year	1 year
e at reaching sexual maturity	Males about 40 mm; females about 40 mm	Males about 50 mm; females about 40 mm
xual dimorphism in spring	Slight in pigmentation	Pronounced in both pigmentation and size
eeding tubercles	Absent	Absent
mber of mature ova counted	50–720	80–196
scription of egg	1.3 mm in diameter, transparent, adhesive	1.5 mm in diameter, transparent, adhesive
ual peak spawning period	Early June	Early June
rritoriality	Probable during spawning season	Probable during spawning season
ult morphology nearly complete	At 3 weeks	At 3 weeks
fluence of sex on growth rate	None	Males grow faster than females
ngevity suggested by study	2+ years	4+ years
fluence of sex on longevity	Males 2+ years; females 2+ years	Males 4+ years; females 3+ years
aximum size suggested by study	78 mm	108 mm
x ratio among young	1.4 males: 1 female	1.1 males: 1 female
grations	Breeding; hiemal	Breeding; hiemal; tributarial
ncipal diet	Aquatic insect immatures	Aquatic insect immatures

[a] Supportive data in Page & Smith (1970).

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(30539—4M—7-71)

LLINOIS BIRDS: Turdidae

ICHARD R. GRABER, JEAN W. GRABER, ETHELYN L. KIRK

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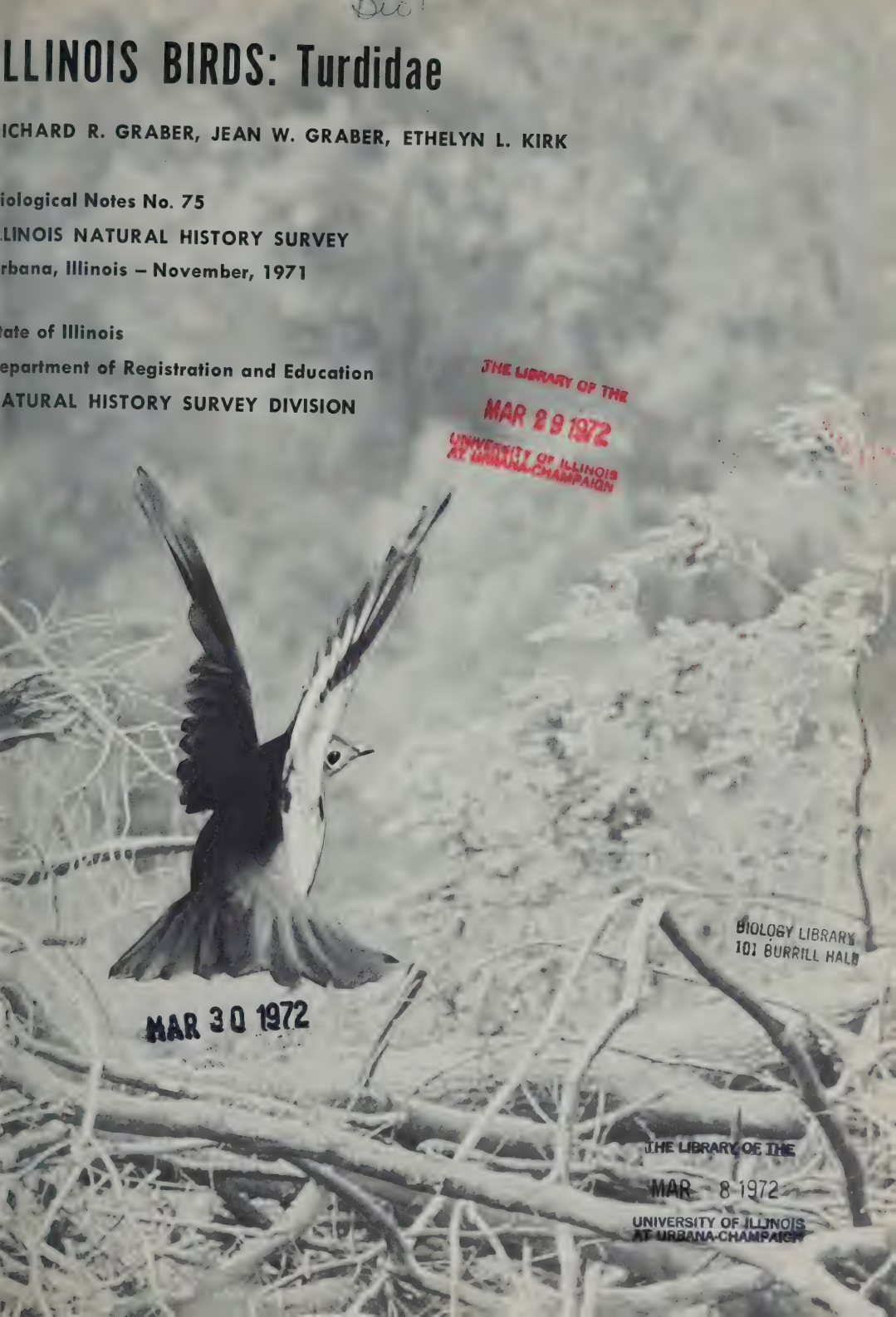

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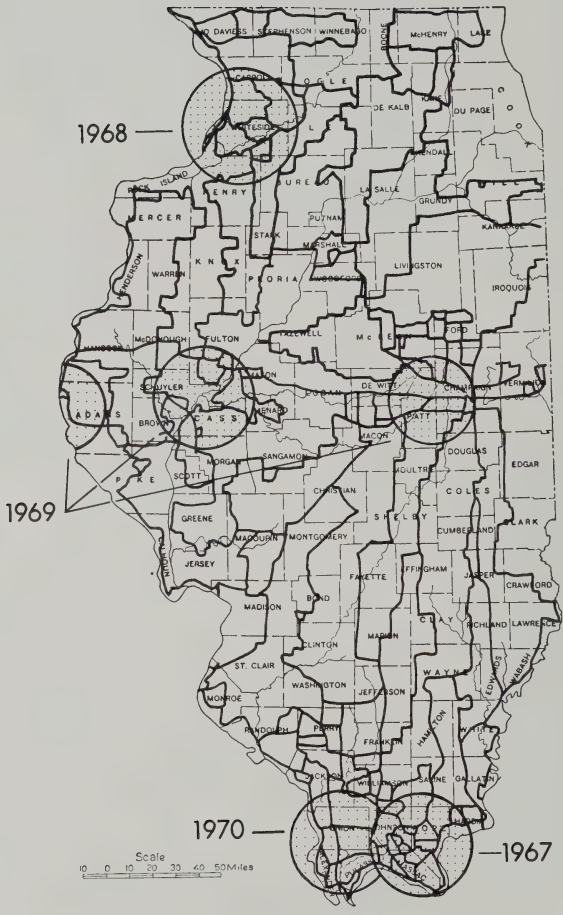


Fig. 1.—Routes travelled (1957–1970) to study breeding distribution of Illinois birds. The encircled areas were special study areas where daily censuses of migrants and nesting populations of birds were carried out, 1967–1970.

INOIS BIRDS: Turdidae

Richard R. Graber, Jean W. Graber, and Ethelyn L. Kirk

THIS IS THE SECOND of a series of papers intended to summarize the available data on the birds inois. The introduction to the entire work was present- the first paper, entitled Illinois Birds: Mimidae ber et al. 1970), and the policies and procedures for eries were outlined therein. This paper deals with the shes, and here we need mention only a few problems of pretation not encountered in the family covered by the er paper.

Our censuses from 1967 to 1970 inclusive were made ely in nonurban habitats, i.e., they represent the coun- le away from towns. Thus, our summer counts for the , which shows a strong preference for human residen- reas, are unrealistically low.

n discussing the robin we are also confronted with the em of large aggregations of birds. Our censuses of the tion for each species are intended to show the num- f birds in their diurnal or foraging distribution among habitats in the study areas we selected (Fig. 1). We interested in the quantitative relationship between nt and breeding populations. We avoided censusing e vicinity of roosts where birds from hundreds of e miles may be aggregated in a small area. At certain ns, robins do form massive roosts, and counts made in reas could be expected to differ greatly from our daily es. Robins are also greatly aggregated during their l migrations, and in graphing our counts of migrants 4) we have sometimes shown two counts for a given ne representing the foraging distribution of the popu- and the other the number of birds in active migra- Thus, for example, our maximum count of robins for 1 in southern Illinois was only about 400 birds seen the day, but during the late afternoon migration 1,600 birds flew over in 1 hour.

ough we tend to be conservative about nomenclatur- nges, we believe that Dilger's (1956) reclassification *ocichla* much better represents the relationships of rthern thrushes, and have, therefore, included the thrush, Swainson's thrush, gray-cheeked thrush, ery under the genus *Catharus*.

the preparation of this paper, we received help from persons. We want especially to acknowledge W. Earl y of the National Museum of Canada, for examining s of our Swainson's thrushes and advising on taxon- roblems in this species, and Donald F. Hoffmeister University of Illinois Natural History Museum for the use of the University collections. We wish to emphasize our gratitude also to the staffs of the State Museum at Springfield, and the Chicago Museum of Natural History Bird Department.

We owe a special debt to Laurence C. Binford of the California Academy of Sciences, who has loaned us his notes on Illinois specimens in the University of Michigan Museum of Zoology and Kansas University Museum of Natural History, plus other notes on Illinois Birds.

To the list of persons who have made contributions of field data on a number of species we need to add the names of Dale E. Birkenholz of Illinois State University, Lawrence G. Balch of Chicago, Mrs. William Carroll, Jr., of Woodstock, Peter Dring of Willow Springs, Everard C. Hall of Chicago Heights, William R. Hawkins, formerly of Carbondale, Marilyn Campbell of the Vermilion County Conservation District, and Natalia Belting of the University of Illinois. For valuable information on one or more species of thrushes, we are grateful to Don Varner of Morrisonville, Paul Heye of Southeast Missouri State College, Robert Russell of Wilmette, Charles Clark of Des Plaines, Alfred Reuss and Karl Bartel of Blue Island, Lee Johnson and Jack Armstrong of Rockford, Mrs. Harry A. Shaw of Sterling, and Elton Fawks of Moline. Elton Fawks also loaned us the notes of John J. Schafer who lived at Port Byron, Illinois, and published many notes on the birds of that area.

We should also mention our colleagues and associates of the Natural History Survey for help with many phases of the project.

Finally, we should point out that much of what is known about the bluebird in Illinois represents the work of one man, the renowned Illinois naturalist, T. E. Musselman. We have depended greatly on his published works for our account of that species.

paper is published by authority of the State of Illinois, IRS Ch. 127, Par. is a contribution from the Section of Wildlife Research of the Illinois Nat- ry Survey. Dr. Richard R. Graber is a Wildlife Specialist at the Survey. Y. Graber is a Research Assistant Professor of Animal Science at the Uni- Illinois. The late Miss Ethelyn Kirk served as Technical Assistant in the Wildlife Research at the Survey.

ROBIN (*Turdus migratorius*)

(Fig. 2 and 3)

Spring Migration

Though one may see robins at any season in Illinois, there are clearly defined migrations in spring and fall (Fig. 4). There is little in the literature to indicate whether the migration is diurnal, nocturnal, or both. Cooke & Widmann (1883) recorded one instance of nocturnal migration. We have seen robins migrating in late afternoon (4:15–6:15 PM CST) in March and April, but whether these flights were sustained into the night, we do not know. We have also observed definite diurnal migrations of robins throughout the morning hours, though more often in fall

Fig. 2.—Robins still largely in juvenal plumage in September.

n spring. There are surprisingly few references to these matic migrations in the Illinois literature (Armstrong 0, Cooke 1883, Fawks 1967, and Musselman 1921), most of them lack precise data on numbers, timing, and ıt directions.

The arrival dates most often given are: February 1–15 southern Illinois, February 6–25 for central Illinois, February 20–March 10 for the north. The earliest ar-ls are likely to be males, but within very few days birds oth sexes are present (Speirs 1946). Our censuses indi-d the presence of high migrant populations in southern ıois from February 10 to April 10, and from about rch 10 to April 20 in central and northern Illinois (Fig. Robins banded in Illinois have been recovered on the hern wintering grounds as late as April 5 (South Caro-), and March 30–31 (Georgia and Mississippi). In tion to the regular spring migration from the South, there are winter (December and January) movements of unknown origin (see under Winter Records, below).

Ballou (1880) believed that northward movements of robins began after a period of 60 hours of warm temperatures (up to 70° F.) and southerly winds. Eifrig (1922, 1924) theorized that photoperiod was a more important stimulus than temperature. Our censuses showed the robin's spring migration to be prolonged in the south, as if the birds tended to loiter at that latitude during February (Fig. 4). This was also Cooke's (1883) impression. The late February exodus of robins from southern Illinois in 1967 occurred overnight when winds shifted from northwest to southwest.

In general, our spring counts of robins were lower in western Illinois than for the eastern side and migrant populations in northwestern Illinois were especially poor (Fig. 4).

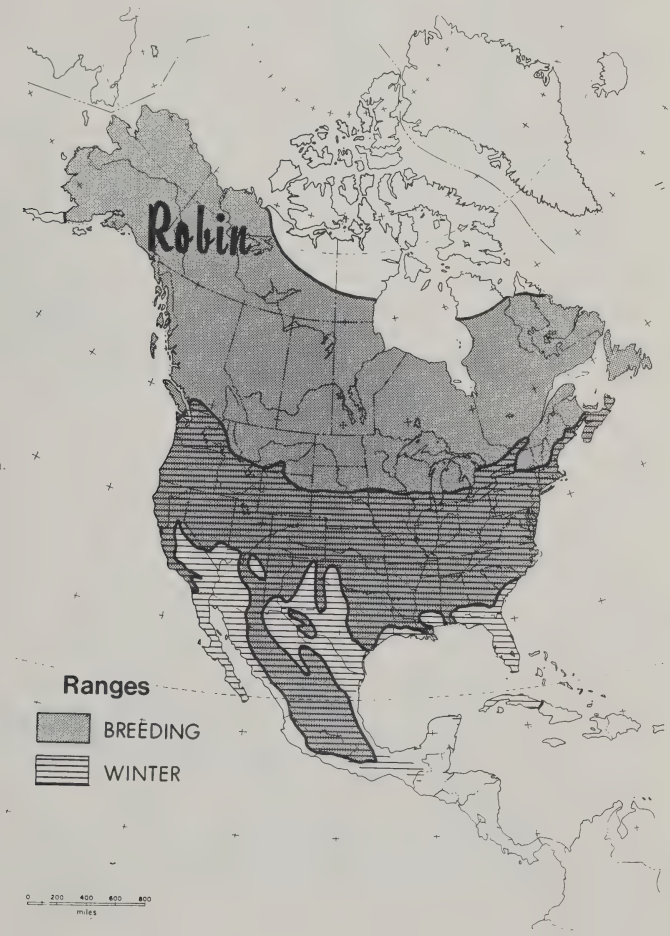


Fig. 3.—General distribution of the robin.

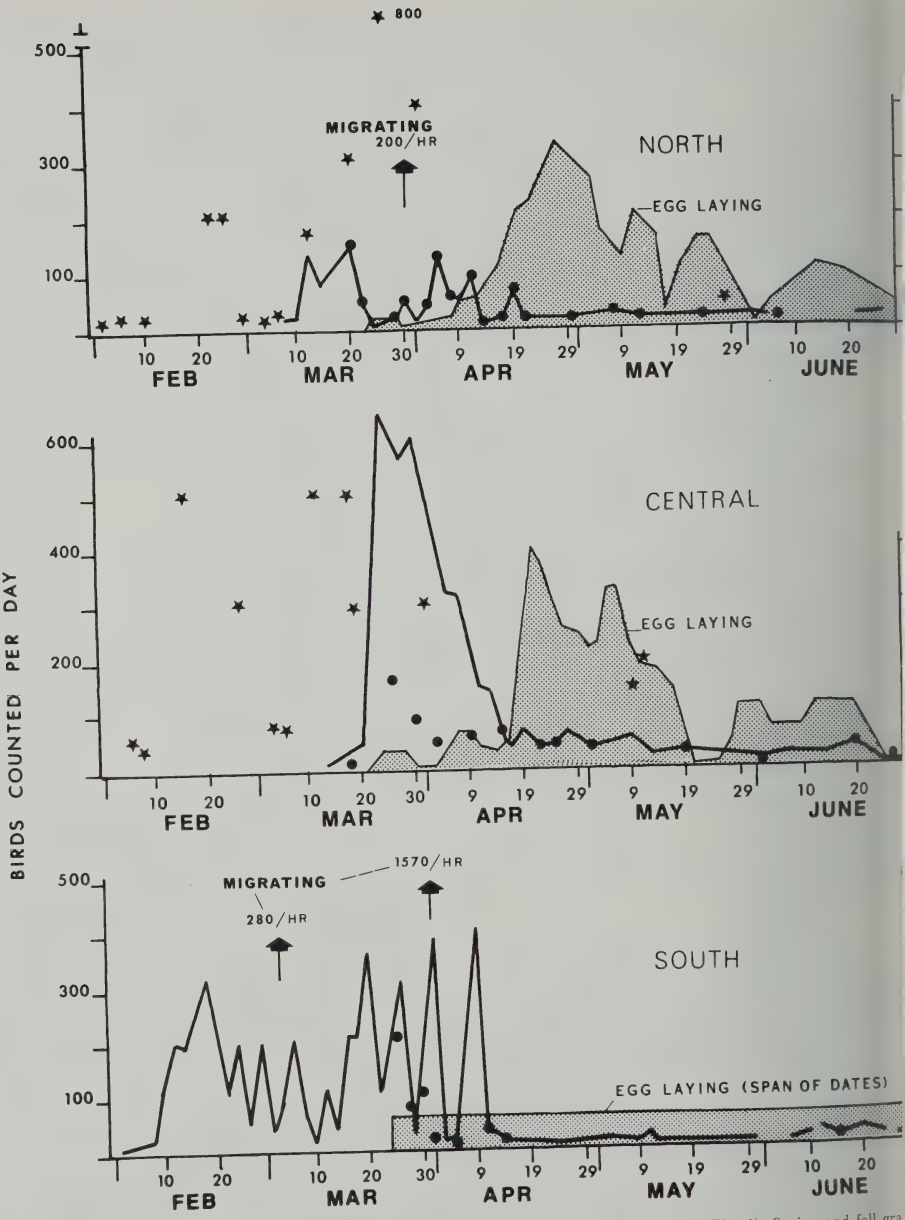
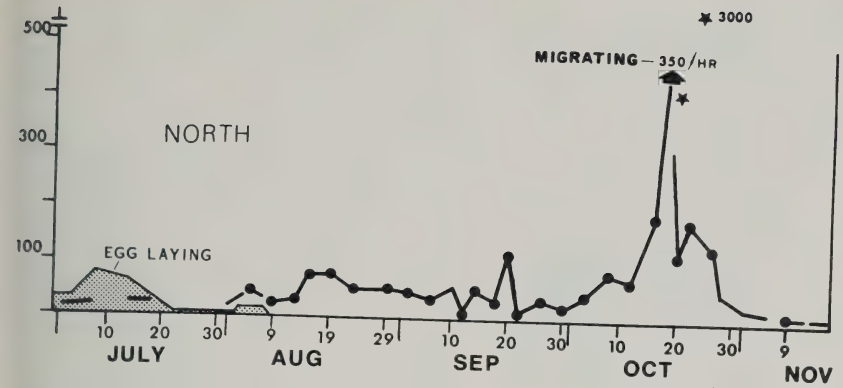


Fig. 4.—Egg-laying and migration seasons of the robin in different areas of the state (see Fig. 1). Spring and fall gra (1967–1970) show the highest daily count of each 2 days (left scale). The lines are interrupted where data have not been collect symbols represent counts made in other years or by other observers. Shaded areas show the percent of eggs laid on a given date (rig or the span of dates during which egg laying has been recorded. Dot symbols represent counts made on the western side of the st without dots represent the eastern side. Arrow symbols indicate dates of actual migration flights and the number of birds seen per ho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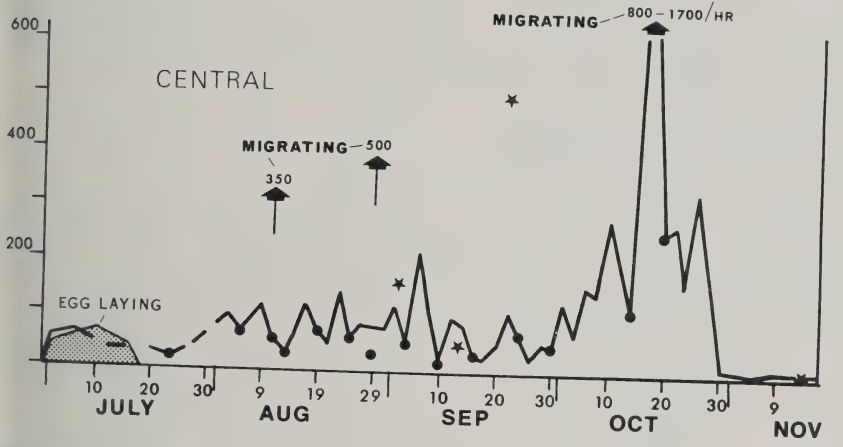
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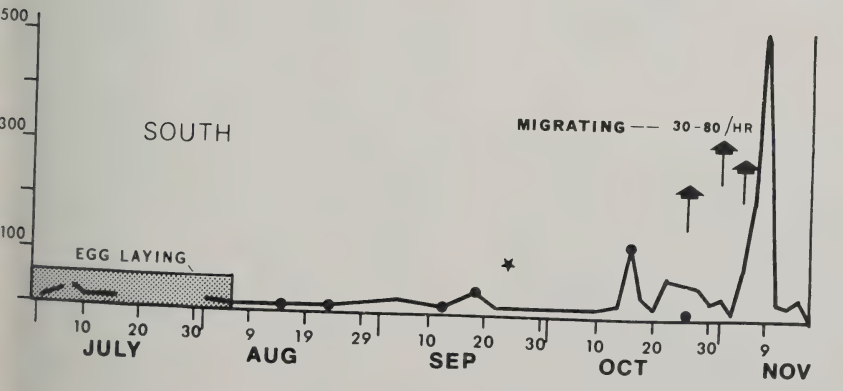
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Distribution

The general distribution of the robin is shown in Fig. 3. Robins surely nest in every township in the State, but as yet the literature does not accurately reveal the distribution (Fig. 5).

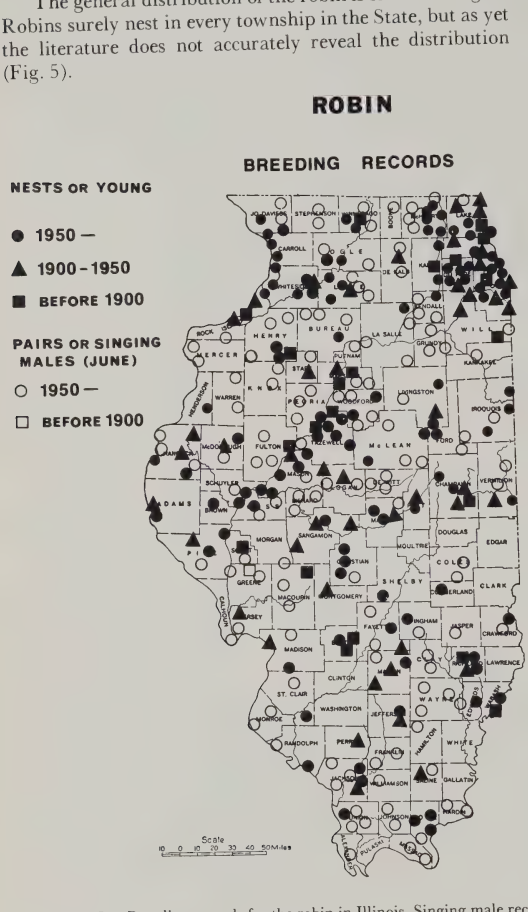


Fig. 5.—Breeding records for the robin in Illinois. Singing male records are for June only.

Nesting Habitats and Populations

The earliest references to the robin in Illinois comment on its domestic nature (Kennicott 1853–1854), and its affinity for human residential areas as nesting habitat has probably increased (Table 1). Ford (1919) noted that while many species disappeared as the city of Chicago developed, the robin remained. Carpenter (1935) believed that the robin had a major influence on the forest edge community at all seasons but winter. Gates' (1911) classification of the robin as a dominant species of mixed forest and of secondary abundance in hedges and orchards is surprising, and the available census data do not bear him out (Table 1). However, there are no census figures available for any sandy-soil areas in the state. A difference in nesting ha tats is apparent between northern and southern Illir (Table 1). There is relatively less use of nonurban habi in the south, where nearly 80 percent of the nesting popu tion is found in towns, versus 60–70 percent in central northern Illinois.

Information on nest-site location in northern and c tral Illinois is summarized in Table 2. The list of pl used is undoubtedly very incomplete. Klimstra & Stieg (1957) provided data on nest sites in Carbondale, Illir There are no studies that relate plant use to plant availa ity.

The recorded heights of robin nests vary from 1 to n than 50 feet above ground. The literature indicates m of nest heights in northern Illinois around 4–6 feet, 1(feet, and 20–25 feet, and average heights of about 7 fee rural nests and 10 feet for urban nests. In both places height tends to increase by as much as 3–4 feet as the se passes. The average height of 73 nests in central Illi was 10 feet, and early-season nests at Carbondale aver about 15 feet (Klimstra & Stieglitz 1957).

We have found no data on territory size for the rob any habitat.

Nesting Cycle

Singing has been recorded in Illinois from late Jan (south) and February (central) to November (Sill 1899 and 1902, Ridgway 1915, and Musselman 1939) rarely at night (Musselman 1931).

For populations in northern Illinois at least, the l ing records show that robins have a strong tendency turn as breeding birds to the vicinity of their birth (F 1945). Published banding data are lacking for souther nois, but Ridgway (1925) recorded a club-footed robi returned to nest each year at Olney.

The nesting season (onset of nest building to fledg last young for the population) lasts from about March September 2 with surprisingly little difference ap between south and north. Single nesting cycles for a p robins required 36–37 days in the north (Charles 190 Leach 1927). Time requirements for different phases cycle have been recorded as follows: 3–10 days fo building (Charles 1909, Scherer 1924, Klimstra & St 1957, and Davis 1969), 11–13 days for incubation (C 1909, Scherer 1924, Leach, 1927, Labisky 1966, and 1969), and 13–15 days for nestling life (Charles Scherer 1924, and Leach 1927).

Maximum egg production occurs between mic and mid-May in central and northern Illinois (Fig. data on the hatching peak presented by Klimstra glitz (1957) indicate a similar curve for the south. are no adequate data on clutch size for southern I but in a sample of 188 nests found in northern and Illinois we see little regional variation. Clutches of seven eggs are rare, representing less than 1 percer sets. Five-egg clutches are uncommon, representi percent of the sets (see also Blocher 1933, and Hess

TABLE 1.—Breeding populations of robins in various Illinois habitats.

Habitat	Acres	Birds Per[a] 100 Acres	Years	Type of Census	Region or County	Reference
idential	8	14	1916	Nest	Richland (S)	Cooke 1916
	20	30	1907–1909	Strip	North & Central	Graber & Graber 1963
	33	36			South	
n residential	160	132	1957–1958	Strip	North	Graber & Graber 1963
	75	109			Central	
	98	102			South	
land estate	100	16	1915	Nest	Cook (N)	Eifrig 1915
shrub (including hedge)	15	34	1957–1958	Strip	North	Graber & Graber 1963
	21	56			Central	
	22	9			South	
ket	13	4	1950	Nest	Jackson (S)	Brewer & Hardy 1950
ard	45	29	1907–1909	Strip	South	Graber & Graber 1963
	36	5	1957–1958		North	
	78	5			South	
shrub	..	28	1966	Nest	Vermilion (C)	Karr 1968
areas	50	4	1907–1909	Strip	South	Graber & Graber 1963
	32	3	1957–1958		North	
	49	2			Central	
	126	2			South	
(all types including edge)	16	6	1907–1909	Strip	Central	Graber & Graber 1963
	60	15			South	
	177	6	1957–1958		North	
	213	6			Central	
	337	+[b]			South	
mland forest	..	12	1966	Nest	Vermilion (C)	Karr 1968
edge	64	8	1943	Nest	Champaign (C)	Johnston 1947
	55	0–4	1927–1948		Champaign (C)	Kendeigh 1944, 1948
	55	(0–20 per mile)	1949–1970		Champaign (C)	Kendeigh, et al. 1950, Kendeigh & Barnett 1968, Kendeigh & Clemans 1970
d oak-hickory forest	24	1	1967	Nest	Hancock (C)	Franks & Martin 1967
d growth or cut-over woods	25	14	1937–1938	Nest	Rock Island (N)	Fawks 1937, 1938
	56	8–12	1941–1944		Sangamon (C)	Robertson, 1941, 1942, 1944
d bottomland	93	6	1955	Nest	Macon (C)	Chaniot & Kirby 1955

[a] figures were converted to read birds per 100 acres or birds per mile of edge (number of territorial males or nests x 2).
[b] ss than one.

nests receive either four eggs or three eggs. In April May, 74 percent of the nests have four-egg clutches, 3 percent have three eggs. In June and July only 46 nt of the nests have four-egg clutches, and 48 percent three eggs. In the south Klimstra & Stieglitz (1957) clutch size to average 3.4 eggs. Data on egg weights ven by Davis (1969).

is a widely held view that robins raise two, and some- three broods per year. Though population studies of ed birds are lacking for Illinois, Young's (1955) data Visconsin support this view. The egg-laying curves several peaks (Fig. 4).

obins are rarely parasitized by the cowbird lmann 1966). We have but one record, in a sample of 00 nests, of a single cowbird egg in a nest with three ggs. The host was successful in fledging young, but wbird egg disappeared.

There are few Illinois data on robin nesting success and productivity. In the nonurban population we studied in northwestern Illinois (Fig. 1), 58 percent of the nests and 50 percent of the eggs fledged young in April and May (sample: 43 nests with complete histories), but in June and July (23 nests with complete histories) nesting success declined to 48 percent of the nests and 37 percent of the eggs. On a school campus in west-central Illinois, Finley (1917) found that only 39 percent of the eggs fledged young in a sample of 64 nests. There are no data on fledging success for the south, nor are there quantitative data on the causes of nest failures. The causes most often mentioned in the literature or observed by us are weather (death of young from cold, or dislodgment of nests by wind and rain storms), and predation by gray squirrels *(Sciurus carolinensis)*, grackles *(Quiscalus quiscula)*, blue jays *(Cyanocitta cristata)*, house cats *(Felis catus)*, and snakes, but the population signifi-

cance of any of these predators is unknown. Lyon (1922) noted particularly heavy predation on robin nests by grackles in 1922, when nearly all observed nests failed.

Finley (1912) and Davis (1969) have described the growth and development of nestlings.

TABLE 2.—Plants and structures used by robins as nest sites in Illinois (mainly nonurban areas).

Nest Site	Percent of Total Nests	
	North (228 Nests)	Central (84 Nests)
Man-made structures (shed, house porch, etc.)	16	12
Osage orange *(Maclura pomifera)*	10	24
Apple and crabapple (*Malus* sp.)	8	10
Elm (*Ulmus americana, U. pumila,* and sp.)	7	10
Oak (*Quercus velutina, Q. borealis, macrocarpa,* and sp.)	8	4
Pine (*Pinus strobus, P. sylvestris, P. nigra,* and sp.)	7	4
Mulberry (*Morus* sp.)	9	1
Box-elder *(Acer negundo)*	4	6
Other maples (*Acer* spp.)	3	6
Cedar (*Juniperus virginiana, J. chinensis,* and sp.)	5	2
Cherry, Plum, etc. (*Prunus serotina,* and spp.)	2	4
Hawthorn (*Crataegus* spp.)	3	2
Spruce (*Picea* sp.)	2	2
Hackberry *(Celtis occidentalis)*	2	1
Willow (*Salix* spp.)	1	2
Honey locust *(Gleditsia triacanthos)*	3	..
Lilac *(Syringa vulgaris)*	3	..
Honeysuckle (*Lonicera* spp.)	+[a]	2
Birch (*Betula nigra,* and sp.)	2	..
Rose (*Rosa multiflora,* and sp.)	1	1
Sycamore *(Platanus occidentalis)*	..	2
Pear *(Pyrus communis)*	+	1
Ash (*Fraxinus* sp.)	1	..
Grape (*Vitis* sp.)	1	..
Catalpa (*Catalpa* sp.)	..	1
Tree of heaven *(Ailanthus altissima)*	..	1
Magnolia (*Magnolia* sp.)	..	1
Pignut hickory *(Carya glabra)*	+	..
Golden bell (*Forsythia* sp.)	+	..
Virginia creeper *(Parthenocissus quinquefolia)*	+	..
Black locust *(Robinia pseudoacacia)*	+	..

[a] Plus symbols (+) = less than one.

Fall Migration

In early September most robins in central Illinois are still in molt, and we have seen young still largely in juvenal plumage as late as mid-October.

Smith (1941) reported that young robins were in full migration in northern Illinois by July 21. We have seen robins flocking in early July wherever there were good food supplies, but whether there is any real migration this early we do not know. Robins banded in Illinois have appeared in the Gulf States at least as early as October 8 (Louisiana) and October 20 (Mississippi). Our censuses show marked day-to-day population changes in July and August in tral and northern Illinois, but very little change in sout Illinois until September (Fig. 4). We have not witn active migrations of robins in any part of the state September, but Robert D. Crompton (personal comm cation) has seen diurnal southward migration as earl August 11 in Mason County. The most massive migrat we have seen occurred in October in northern and ce Illinois near major waterways. Though all of the fall r migrations we have seen were oriented either near s (180°) or west of south, the recoveries of banded birds s great dispersal (Fig. 6). We have seen more morning rations of robins in the fall, and more evening flights i spring. The robin is a rare casualty at television to We have found only one specimen (on October 6, 1 among thousands of night migrants (of other spe picked up at towers in central Illinois.

Highest fall populations occurred in September October in central and northern Illinois, and in Oc and November in the south (Fig. 4). Fall counts of r were three to four times higher in east-central Illinois in the west.

In the north we saw about four robins in the (August–October, inclusive) to one in the spring (M and April). In the central sections, both east and wes saw only about 1.5 in the fall to one in the spring. I south the ratio was, inexplicably, reversed: three in s (February through April) to one in fall (. ust–November, inclusive). These data represent "grounded" robins, and not birds in active migration.

A notable ecological change occurs in the robin bet spring, when most birds are found foraging in open g land, and fall and winter when the population freq woody habitats much more.

Roosting

We have no records of Illinois robin roosts that approach the dimensions of those found in eastern souri, where as many as 3½ million birds have be ported (Petersen 1965, and Widmann 1895). James studied local roosts in Champaign County, and roost also been recorded in Cook County (Back 1934–193 Bailey 1932), and in Fulton County where the popu peaked at 22,500 birds on October 23. Roosting ag tions occur in spring from March into May, and i summer and fall from July through October (James Large winter roosts should be looked for especia southern Illinois.

Winter Records

Robins have been found in winter throughout m the state (Fig. 7), but generally only in small nu north of the southern zone (Fig. 8), and the bulk of th ern robin population winters south of latitude 35° i.e., south of Illinois (Speirs 1953). Though there a cember and January records for the Chicago area in 3 of the past 40 years (1930–1969), our statewide ce

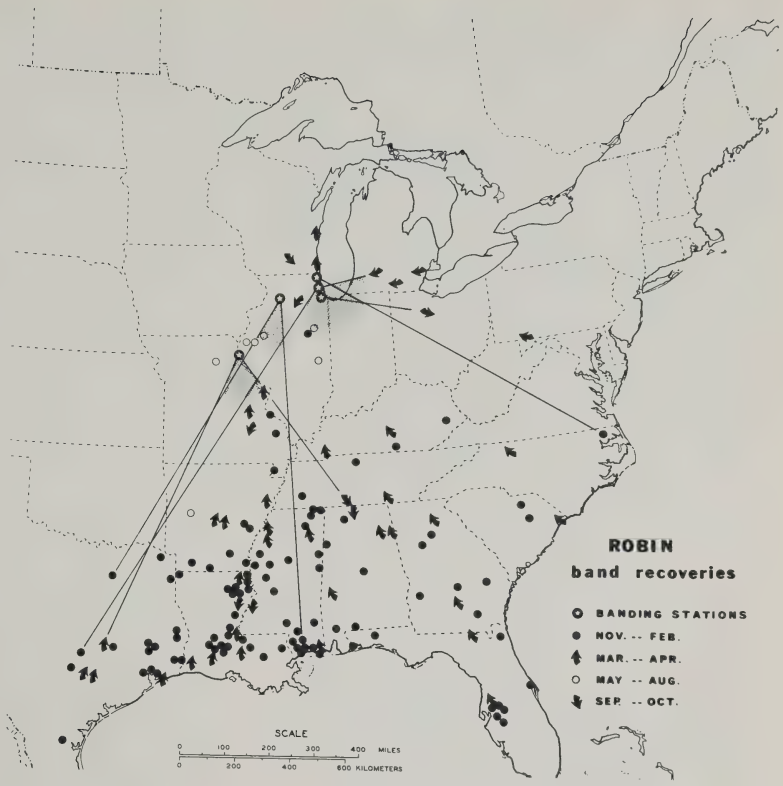


Fig. 6.—Distribution of recov- of robins banded in Illinois. and shaded areas indicate the d of recoveries from five band- ations.

ed that 99 percent of the state's winter robin popula- vas in the southern region (Graber & Graber 1963). ome winters (note especially 1955–1956, 1964–1965 g. 8) large numbers of robins appear even in northern entral Illinois. In such high years hundreds or even sands of robins may be seen per day in central and ern Illinois (Fawks 1967, Musselman 1963, Link , Mayfield 1951, and Rice 1946). Various explana- have been offered for these high populations, and are some data to support the following hypotheses: nusually high productivity in the preceding breeding n, productivity that increased population pressure where in the eastern United States; (2) exceptionally winter food reserves in the north; and (3) exceptional- ly northward migration, reflecting an unusually mild r (Robbins 1956, and Nolan 1956).

ooke (1885) believed that bottomland forest was the 's primary winter habitat (note also the winter distri- n, Fig. 7), but there are few population measurements ble for any habitat. Between 1927 and 1970, Ken- and his students reported populations in forest edge ntral Illinois ranging from none in most years eigh 1948) to eight birds per mile of edge (Kendeigh st 1958). In southern Illinois, Shaw et al. (1961, 1965) recorded populations in a shrubby field ranging from none (1961) to 13 robins per 100 acres (1965).

Food Habits

Forbes' (1903) studies were based almost entirely on specimens from central and northern Illinois. In the spring robins fed almost exclusively on animal matter (Fig. 9). The items most frequently mentioned in the literature are earthworms and larvae of March flies, especially *Bibio albipennis* (LeBaron 1853–1854, Thomas 1920, Rice 1946, and Twomey 1945). Forbes' studies showed the *Bibio* larvae to be important, but did not show the expected prevalence of earthworms (Fig. 9). He related the low tally of worms to their quick digestibility. Cutworms (Noctuidae), and even the egg masses of tussock moths (Liparidae) are prominent in the diet (Hulsberg 1917–1918, and Schantz 1933), as are ground beetles (Carabidae) and wireworms (Elateridae) later in the spring. At a Tazewell County orchard that was heavily infested with canker worms (Geometridae), Forbes (1883) found that robins increased their intake of the pest, but kept many other items of their usual diet. Cleveland (1923) found robins feeding 17-year cicadas to their young.

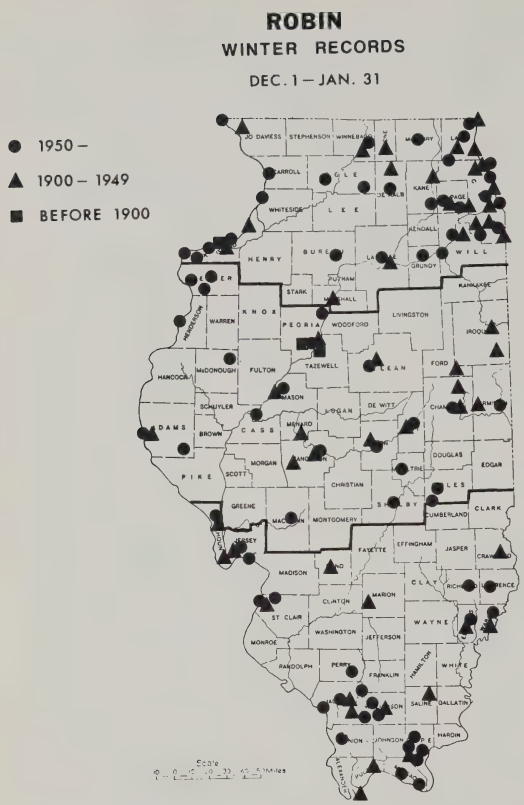


Fig. 7.—Winter records for the robin in Illinois. The three regions of the state discussed in the text are shown by heavy lines.

In June a change to a primarily fruit diet occurs, and fruit (much of it wild) is very important through the rest of the summer and fall (Fig. 9). In late summer and fall (particularly October) we have observed robins feeding heavily on wild grape (*Vitis* sp.), black cherry (*Prunus serotina*), *Parthenocissus,* hackberry (*Celtis* sp.), dogwoods (notably *Cornus racemosa, C. rugosa,* and *C. stolonifera*), multiflora rose, pokeberry *(Phytolacca americana),* elderberry (*Sambucus canadensis*), persimmon (*Diospyrus virginiana*), and red cedar (see also Hulse 1912, Bell 1956, and Cone 1963). Other fruits commonly recorded as robin food are: mountain ash (*Sorbus* sp.), sumac (*Rhus* sp.), barberry (*Berberis* sp.), bittersweet (*Celastrus scandens*), holly (*Ilex decidua*), snowberry (*Symphoricarpos* sp.), pear (*Pyrus* sp.), apple (*Malus* sp.), and greenbrier (*Smilax* sp.) (Cooke 1885, Musselman 1934–1935 and 1963, Holcombe 1936, and Pitelka 1936). At least one instance of robin intoxication from fermented hackberries has been recorded (Buck 1936). Forbes' (1903) only winter specimen (from Cairo) contained fruit of mistletoe (*Phoradendron flavescens*) exclusively, but local observers felt that winter robin pop tions in that area depended mainly on wild grapes and a failure of the grape crop was reflected in reduced w populations. Cooke (1885) also noted that robins fed h ly on wild grapes in southern Illinois.

Forbes (1900) believed the robin to be function controlling cutworm numbers, and Rice (1946) estim that robins consumed about five-sixths of the invertel population in leaf litter at a forest edge in Champ County.

Charles (1909) recorded that both adults fed the yo putting in a 15½-hour day in late May, and bringin average of 356 pieces of food per day. Lepidoptera l comprised about 50 percent of the total food, with e worms (about 29 percent), ants (about 7 percent), Di (about 6 percent), and small percentages of Coleop Myriapoda, and adult Lepidoptera making up most o other half. Earthworms as food for the young have been recorded by Mann (1908) and Scherer (1924).

Longevity and Mortality

Based in part on northern Illinois banding data, F (1945*a*) determined the average natural longevity for in to be 1.7 years. He estimated the age group compo for the population as follows: first-year birds, 53 pe second-year birds, 25 percent; third-year birds, less th percent; fourth-year birds, less than 6 percent; fifth birds, less than 2 percent; and sixth-year or older bird than 1 percent. A sample of 28 returns of robins ban northeastern Illinois produced six birds past 3 ye age, one past 4 years, and one past 6 years (Dov 1949). A robin, recognizable because it had white feathers, was seen regularly in the breeding season at dale in 6 successive years (Tuttle 1927), and Ba (1968) oldest banded robin was nearly 5 years old.

As to the causes of robin mortality in Illinois, the ture has dealt in detail with only one type—insecticid soning. Bartel's studies in Cook County (1960, 1962, are particularly valuable because he studied a bande ulation for which he had a long-term population reco established that 85–90 percent of the robin populatio eliminated following application of 2 pounds of hept per acre for Japanese beetle (*Popillia japonica*) cont year after treatment the robin population had rec only 5 percent, but 2 years after treatment it was bac percent of the pretreatment level (Bartel *fide* Mu 1960 and Graber 1962).

A robin population was eliminated (as evidenced recovery of dead birds and the disappearance of robin established nests) in an area of Iroquois County by t plication of 3 pounds of technical dieldrin per acre, for Japanese beetle control (Scott et al. 1959). Large bers of dead earthworms were seen following the trea and this was believed to be the route-source of the to in robins (see also Barker 1958). Very high robin mo from DDT application has also been re (Montgomery 1956).

Severe weather in late winter or spring may be a

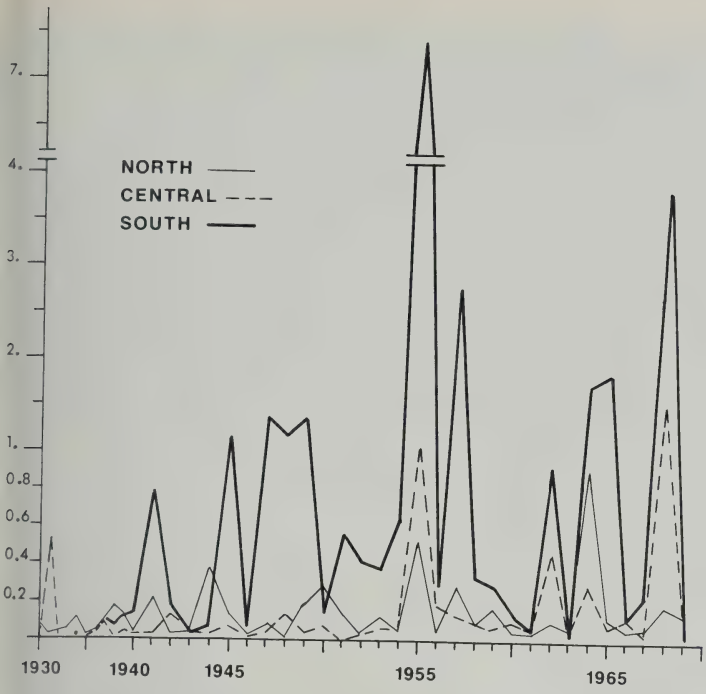
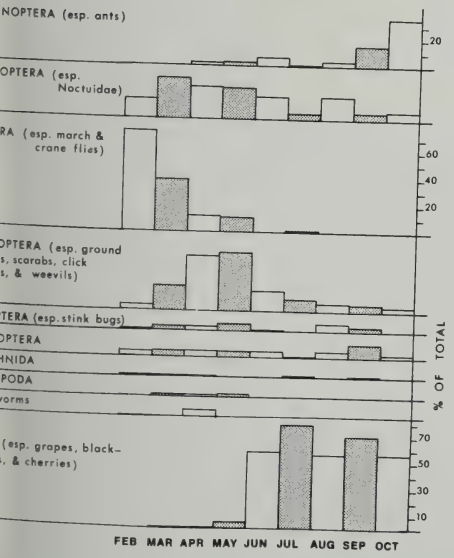


Fig. 8.—Annual variation in winter robin populations, based on Audubon Christmas counts in three regions of the state. Graph line shows the number of robins seen per party hour. (For information about the Audubon Christmas counts, see Cruickshank 1970.)

ROBIN - FOOD



g. 9.—Food habits data on the robin from the study of Forbes, 880). Percentages represent the part of the total food identified in achs of several robins examined each month.

icant mortality factor in robin populations, as it is in bluebird populations. Dead robins and reduced populations have been recorded in northern Illinois following severe wind, cold, or snow, especially in April (Butler 1896, Blocher 1921, Schafer 1921, and Segal 1960). Roseberry (1962) found robins among the dead birds picked up near Carbondale following prolonged snow and cold in February and March.

VARIED THRUSH (*Ixoreus naevius*)

(Fig. 10)

Because there are at least 16 records of this species from 14 different localities in the state, its occurrence cannot be considered accidental. Only one record was found in the literature before 1950 (Fig. 11) and there were four in 1970 (Armstrong 1970). All records are from northern Illinois with the exception of one wintering at Decatur (Lobik 1957). All dates given fall between mid-December and March 30 with one exception (April 26, 1929 at Blue Island, Bartel 1932).

The usual pattern of behavior is that a single bird, most often a male, will appear at a feeder (or area providing food such as crab apples) around Christmas time and remain for several weeks. This far northwestern breeder seems to be a habitual winter wanderer, occurring fairly regularly in northeastern United States and spottily as far southeast as the Gulf Coast (Keith 1968).

Fig. 10.—Male varied thrush photographed near Rockford, Illinois in January, 1970 by Jack Armstrong. This is a valuable photographic record of a species rare in Illinois. The bird is actually about the size of the robin.

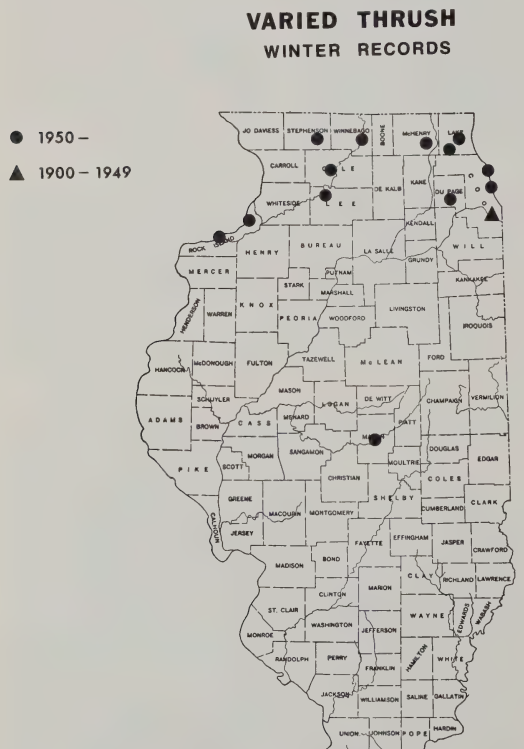


Fig. 11.—Winter records for the varied thrush in Illinois.

WOOD THRUSH (*Hylocichla mustelina*)

(Fig. 12 and 13)

Spring Migration

The available evidence, notably fall kills at televis towers, indicates that wood thrushes are night migra but we have never heard a recognizable wood thrush among the many *Catharus* calls we detect every migrat season in Illinois.

March records for this species (George 1968) must accidental even in southern Illinois, and should be care ly documented with full details. We are skeptical eve early April records (Ford 1956, and Sparks 1905), espec ly in northern and central Illinois. In most years the wood thrushes reach southern Illinois about April 15, tral Illinois about April 22, and northern Illinois a April 29. Within a week the species becomes common, peak numbers may be seen in all parts of the state a May 6–20 (Fig. 14).

We saw the largest numbers in the south and fewe the north, and our counts in southern and central Illi were consistently higher on the western side of the than on the eastern side (Fig. 14).

There are no published band recoveries of Illinois w thrushes for any season.

Distribution

The general distribution of the wood thrush is show Fig. 13. The breeding distribution in Illinois is very p known, especially in any quantitative detail (Fig. 15).

Nesting Habitats and Populations

The favorite nesting habitat of the wood thrush ap to be lowland forest (Ridgway 1887, Loucks 1891 Fawver 1947). Ridgway (1915) was concerned abou thrush because of the clearing of the lowland forests this problem is much more critical now. Cahn & H (1929) mentioned that wood thrushes breed in cy swamps.

The species also nests in upland forest, and even in dential habitat and shrub areas (Table 3). Riis (1 Gault (1933), and Musselman (1921*a*) reported good ing populations in northern and western cities, but recently we found measurable urban populations o the south (Graber & Graber 1963).

Wood thrush territories in central Illinois forest sured by Twomey (1945), Fawver (1947*a*), and (1953) varied from about 2 to 7 acres. The most de data are those of Calef who found extremes of 1.7 acres, with an average of about 3 acres.

There are nest site data on only 29 nests. The most favored were elms (31 percent of nests) and (17 percent). Although heights of nests ranged from 2 feet, most of the nests (71 percent) were 5–10 feet high

12.—Wood thrush, the most heavily spotted of Illinois thrushes.

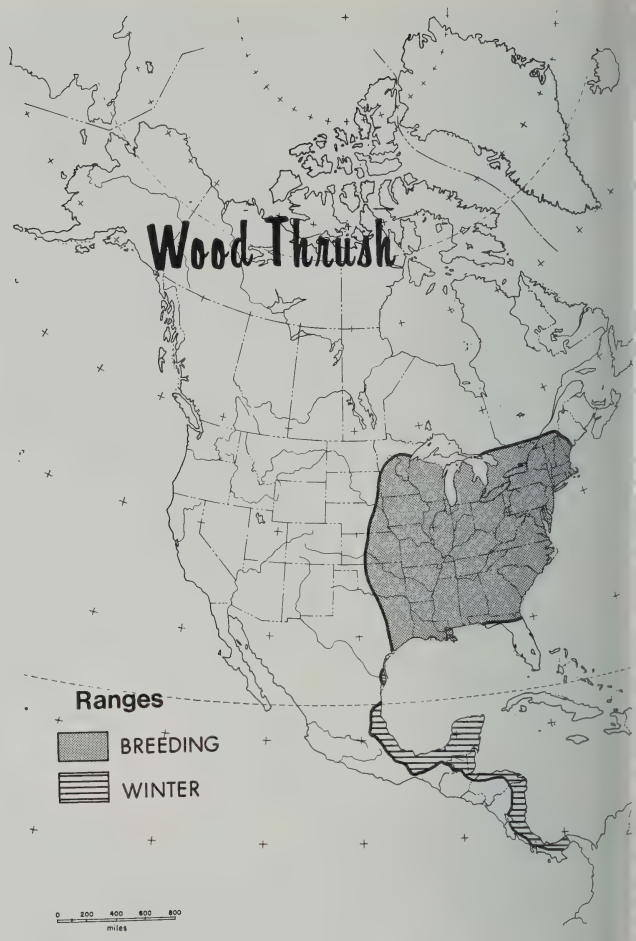


Fig. 13.—General distribution of the wood thrush.

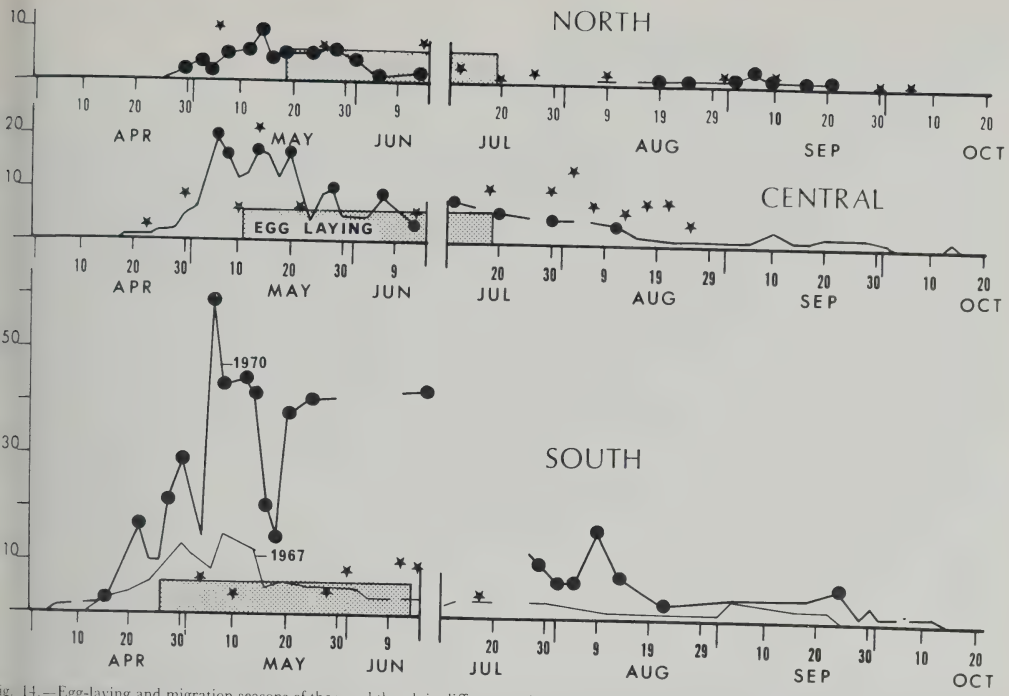
Nesting Cycle

The Illinois literature is essentially devoid of quantitative data on the nesting cycle of the wood thrush and we can add little. Singing has been recorded from April 19 in southern Illinois to August 3 in the north. Our records on the span of dates for egg laying, from April 26 in the south to July 19 in the northern and central regions, are very incomplete, particularly for the south. A record of young leaving the nest May 30 in the Chicago region (Ford 1956) must be exceptional as an early nesting record for that latitude.

There is a very high incidence of cowbird parasitism. From our records and the literature, we have egg data on only 69 wood thrush nests in Illinois, of which 33 (48 percent) were parasitized. Most of the nests had 1 or 2 cowbird eggs, but 6 nests had 3 or more (up to 5). Though the ple is small it represented all three regions of the stat the incidence of parasitism was near 50 percent in ea gion. This high parasitism has been reported over years. Mundt (1883) found nearly half of the nests the Vermilion river bottoms parasitized. Twomey recorded fledging success of 78 percent for 23 thrush nests), and 33 percent for 3 cowbird eggs (3 nests).

In the sample of 36 nonparasitized nests, clutch were as follows: 5-egg, 9 percent; 4-egg, 76 percent; 15 percent.

There are no data on longevity or on mortality f Montgomery (1956) felt that wood thrushes survived than robins following DDT applications for elm d because the wood thrushes arrived later after the inse treatment.



ig. 14.—Egg-laying and migration seasons of the wood thrush in different regions of the state (see Fig. 1). Spring and fall graph lines (1967-1970) ighest daily count of each 2 days. The lines are interrupted where data have not been collected. Star symbols represent counts made in other years or er observers. Shaded areas show the span of dates of egg laying. Dot symbols represent counts made on the western side of the state; lines without present the eastern side.

Migration

/e have seen wood thrushes still in molt as late as Sep- er 20 in central Illinois, and specimens killed at televi- towers often show a few pin feathers in the body age in late September.

/hen silent, wood thrushes are difficult to find, and silence probably has much to do with the relative lack records (Fig. 14). We have recorded only 1 in the fall ery 15–20 in the spring. After the singing ends, in August, one occasionally hears the thrush's distinctive notes, but generally the species goes undetected.

latively few wood thrushes are killed at Illinois tele- towers. In a sample of several thousand specimens up in central Illinois, this species comprised only 0.5 percent. They have been killed in migration at s early as September 12 and as late as October 14.

ir censuses indicate that the migration is largely h by the end of September (Fig. 14). There are rec- or the wood thrush in northern Illinois in mid-No- and late November (Fawks 1970, and Holcombe but these must be considered accidental. A winter for southern Illinois (Harlow 1921) is of doubtful

Food Habits

Forbes (1903) examined the stomach contents of 22 wood thrushes taken from April to September, probably in central Illinois or central and northern Illinois. He found that among the thrushes and mimids, the wood thrush was near the top in the amount of insects taken (71 percent of the diet), and low in fruit consumption (19–21 percent). In the spring, the wood thrush was exceptional in the amount of millipeds it consumed (13 percent), and it also fed heavily on ants (15 percent). Coleoptera (18 percent of the diet) were important, consisting mainly of ground beetles, scarabs, click beetles, wireworms, and weevils. Forbes believed the wood thrush consumed fewer predaceous beetles than other thrushes. Flies, notably larvae of crane flies and *Bibio*, made up 12 percent of the food. Spiders and harvestmen made up about 1 percent of the diet, and molluscs about 1 percent. Rice's data (1946) on food habits of the wood thrush are roughly comparable to Forbes' data, though Rice indicated larger numbers of Hemiptera (10–20 percent) in the diet than did Forbes (only 1 percent).

In September we have seen wood thrushes feeding on the fruit of spicebush (*Lindera benzoin*), and pokeweed.

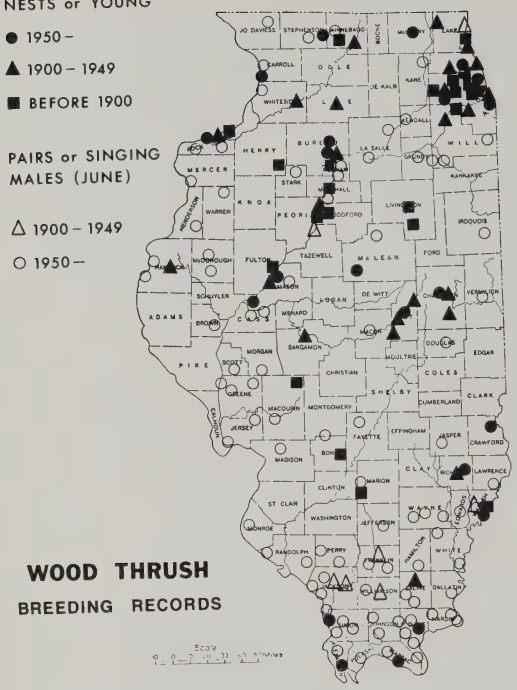


Fig. 15.—Breeding records for the wood thrush in Illinois. Singing male records are for June only.

HERMIT THRUSH (*Catharus guttatus*)

(Fig. 16 and 17)

Spring Migration

Though the hermit thrush has been recorded in w at localities throughout the state, the winter populati so generally thin that the onset of the spring migratic late March is conspicuous (Fig. 18). The hermit is the cold tolerant of the *Catharus* thrushes, and arriv spring nearly a month in advance of the other three sp (Annan 1962), passing through the state before the species reach peak populations. Most of the hermit th population is north of Illinois by the end of April, and are very few spring records later than May 12 ev northern Illinois (Fig. 18). The peak numbers of he probably occur in southern Illinois April 1–15, and i central and northern regions April 10–30.

The hermit is the quietest of the four *Catharus* th es. In contrast to the loud calls of the other specie hermit's note is soft and low. Our phonetics for the c "tock" "tuck," or "trock," and the call is not heard so often as the calls of the other species. We have heard the hermit's call from night migrants, and ou indicators of the timing of migration are the few h killed at night on television towers in the fall. We hav er heard a hermit thrush sing in Illinois, though th sing occasionally in the northern region of the (Farwell 1919, and Craigmile 1945).

Views as to the abundance of the hermit thrush markedly. Nelson (1876–1877) noted that the speci

TABLE 3.—Breeding populations of wood thrushes in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Virgin bottomland forest	77	21	1948	Nest	Sangamon (C)	Snyder, et al. 1948
Bottomland forest	..	20	1966	Nest	Vermilion (C)	Karr 1968
	..	12–24	1946–1951	Nest	Piatt (C)	Weise 1951
Upland forest	..	6–10	1946–1951	Nest	Piatt (C)	Weise 1951
Forest edge	60	0–2	1959–1962	Nest	Piatt (C)	Balda 1963
Oak-maple forest	55	0–14	1927–1948	Nest	Champaign (C)	Kendeigh 1944, 1948
	55	0–10	1949–1970		Champaign (C)	Kendeigh & Brooks 196 Barnett & Balda 1966
	64	12	1943	Nest	Champaign (C)	Johnston 1947
Upland oak-hickory forest	24	5	1967	Nest	Hancock (C)	Franks & Martin 1967
Forest (all types including edge)	79–98	1	1957–1958	Strip	North	Graber & Graber 1963
	97–117	0–1			Central	
	166–174	3–6			South	
Second growth or cut-over woods	15	40–93	1937–1938	Nest	Rock Island (N)	Fawks 1937, 1938
Late shrub	..	14	1966	Nest	Vermilion (C)	Karr 1968
Shrub areas	62–67	3–6	1957–1958	Strip	South	Graber & Graber 1963
Grazed bottomland	93	1	1955	Nest	Macon (C)	Chaniot & Kirby 1955
Swamp and thicket	13	2	1950	Nest	Jackson (S)	Brewer & Hardy 1950
Urban residential	98	2	1958	Strip	South	Graber & Graber 1963

[a] All figures were converted to read birds per 100 acres (number of territorial males or nests x 2).

y abundant in northeastern Illinois, and Nehrling 80) found it not very common in the north. Judging n the counts of other observers (Annan 1962, Eiseman Shank 1962, Clark & Nice 1950, and Labahn 1941), mit thrushes appear to be more common along the lake in northeastern Illinois than in any other section of the state. A large kill of hermit thrushes by a storm at the south end of Lake Michigan on April 16, 1960 (Segal 1960) also tends to support the view that hermit thrushes become concentrated at the lake. We found the hermit thrush least

16.—Hermit thrush, generally the most heavily spotted of the Illinois *Catharus* thrushes. (It also has a conspicuously reddish tail.)

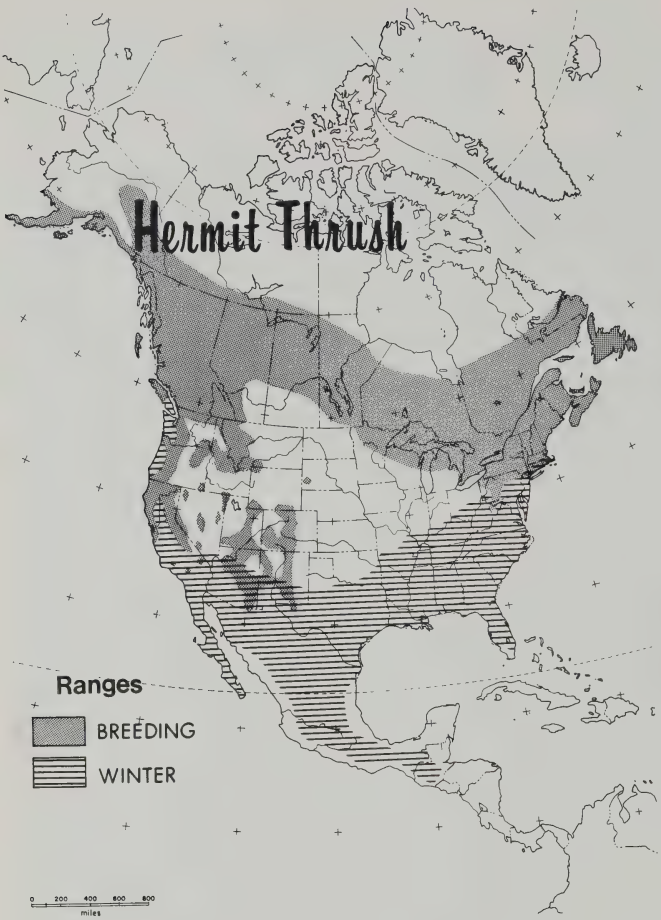


Fig. 17.—General distribution of the
thrush.

common in southern Illinois, possibly because of the large amount of concealing cover.

Fall Migration

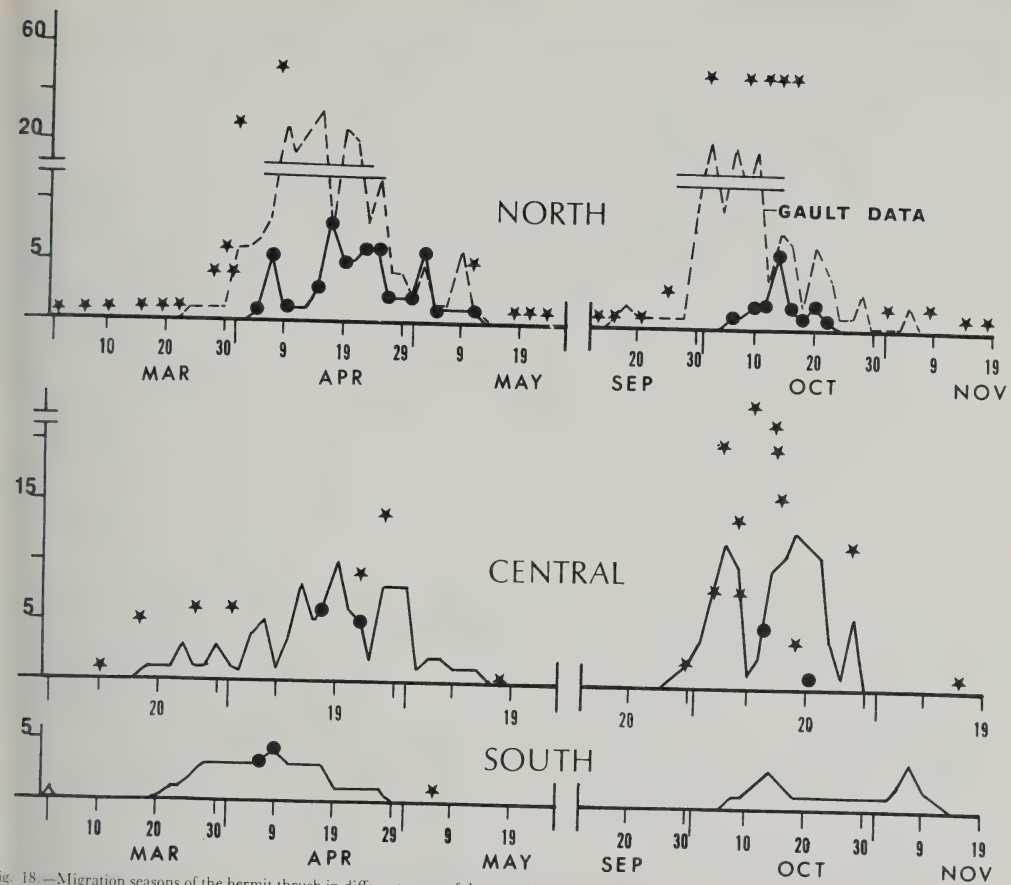
After the spring migration hermit thrushes are generally not seen in Illinois again until mid-September or late September (Fig. 18). Though there are a few August records (Ford 1956), we are inclined to discount them either as accidental records or misidentifications. Most of the hermit thrushes pass through Illinois in October, and nearly all are gone by November 15. Bennett (1952) has shown that the strong October cold fronts often bring large numbers of hermits to the lakeshore of northeastern Illinois (see also Jung 1925). The largest numbers are seen on the first two days after the cold front passes. As in the spring, the numbers of hermit thrushes are low in southern Illinois (Fig. 18).

Though the other species of *Catharus* thrushes ar
quently killed at television towers, hermits escape with
few casualties, about .02 percent of the thousands of
we have observed as tower victims.

Recoveries of hermit thrushes banded in northea
Illinois during fall passage (Fig. 19) have been w
spread in the Gulf States (Bartel 1935, Downing
Jurica et al. 1959). Reuss (1953) recorded an indiv
hermit thrush staying as long as 2 weeks in the same a
northeastern Illinois during October.

Winter Records

There are scattered winter records of the hermit t
for all sections of the state (Fig. 20), but there are no p
measurements of winter populations. Our own ce
(Graber & Graber 1963) showed measurable popul
only one year out of two, and then only in the south,



ig. 18.—Migration seasons of the hermit thrush in different areas of the state (see Fig. 1). Spring and fall graph lines (1967–1970) show the highest ount of each 2 days. Star symbols represent counts made in other years or by other observers. Dot symbols represent counts made in west-central Il- lines without dots represent the east. Dashed graph line (north) represents the cumulative counts of birds made by Benjamin T. Gault between nd 1927 mainly in Du Page County, and shows the long-term peaks and range of migration dates.

und one to two hermit thrushes per 100 acres in forest hrub areas. The Christmas counts also show great al variation in the hermit thrush population (Fig. 21). me years more hermits have been found in northern is than in the southern region, but such records were bly more a reflection on the distribution of observers distribution of the birds. Cooke (1885) reported high r populations (5–20 hermits seen per day) in thickets the Mississippi River, but no recent observer has rec- comparable numbers. In a 3-day census at Grafton, 1940) found only two hermit thrushes. Bartel (1954) ed three in a day near Lisle (January 17, 1954), in a hen the Christmas counts indicated high populations south (Fig. 21).

tler (1896) suggested that hermit thrushes suffer the ype of cold mortality in the winter and spring that is able in bluebird populations, and James' (1961) studies support this view. The low populations in 1958, 1959, and 1960 probably refflect such mortality.

Food Habits

In his studies, Forbes (1903) examined 21 specimens of hermit thrushes, which were nearly all taken in the spring in northeastern Illinois. Even for a thrush, the amount of insects eaten by hermits was high (84 percent of all food). Coleoptera (29–30 percent) were of major importance, especially predaceous ground beetles. Forbes noted that the spring migration of the hermit thrush is timed with the emergence of many beetles. Gault (1884–1889, unpublished notes) also found beetles to be the principal food. Lepidoptera (18–19 percent), and ants (13–15 percent) formed much of the rest of the diet. Like the wood thrush, hermits ate more millipeds (12 percent) than most birds.

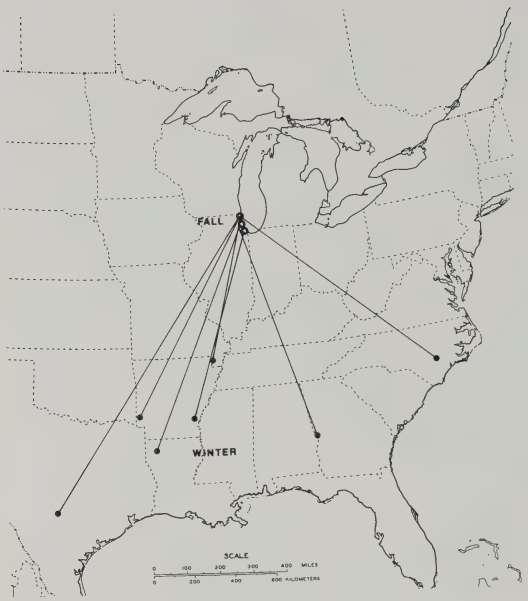


Fig. 19.—Winter and early spring recoveries of hermit thrushes banded in northeastern Illinois during fall migration.

Grasshoppers (7–8 percent), Hemiptera (7–8 percent), and spiders (4 percent) made up most of the remainder.

Forbes found no fruit in the diet, but he examined only two fall specimens. We have found hermit thrushes to be very found of pokeberries, and have also seen them feeding on wild grapes in October. Nothing has been recorded on the winter food.

Fig. 20.—Winter records for the hermit thrush in Illinois. T regions of the state discussed in the text are shown by heavy lines.

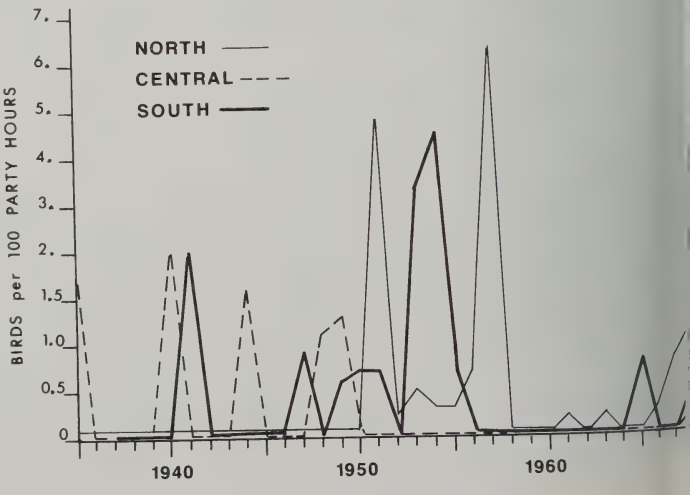


Fig. 21.—Annual variation in winter hermit thrush populations, based on Audubon Christmas counts in three regions of the state. Graph lines show the number of hermit thrushes seen per 100 party hours. (For information about the Audubon Christmas counts, see Cruickshank 1970.)

VAINSON'S THRUSH *(Catharus ustulatus)*

(Fig. 22 and 23)

ring Migration

Swainson's thrushes generally begin to appear in Illi-
s in small numbers about April 20, with not more than a
ek to 10 days difference in arrival between south and
th (Fig. 24). Though there are records for the north as
ly as March 31 and early April (Ford 1956 and Abbott
l. 1933) we suspect that these are based on misidenti-
tions of hermit thrushes. Most Swainson's thrushes
s through Illinois during May, with peak populations
sing the south in early and mid-May and the central
north in mid-May and late May (Fig. 24). A few
inson's thrushes regularly linger in central and north-
Illinois through the first week in June.

The migrations are probably strictly nocturnal, some-
es lasting all night (Cochran et al. 1967, and Kjos &
hran 1970). The migrations are often audible because
he birds' loud calls, which are uttered during the day
. We translate the calls most frequently given as
eek" and "whit." More rarely the calls sound like "sweeur" or "peeur," which are much more characteristic of gray-cheeked thrushes and veeries. Swainson's thrushes are also strong singers during migration.

We saw the largest numbers of Swainson's thrushes in east-central Illinois, and the fewest in the south (Fig. 24). The pattern of high populations in the east is, in our experience, consistent from year to year. There are no absolute measurements of migrant thrush populations for any locality in Illinois, nor has anyone attempted a precise definition of thrush habitat. We see them in a wide variety of woody habitats.

Fall Migration

There are a few July records for the Swainson's thrush in northern Illinois (Nelson 1876–1877, Ford 1956, and Eiseman & Shank 1962), but generally the first indication of the fall migration comes in mid-August or late August (Fig. 24). At Glen Ellyn, Gault (unpublished notes 1884–1915) fairly regularly detected the first fall Swainson's thrushes around August 20. One specimen he collected on August 21, 1895 was in heavy molt. The first birds to

g. 22.—Swainson's thrush. (The thrush with buffy "spectacles.")

Fig. 23.—General distribution of the S son's thrush.

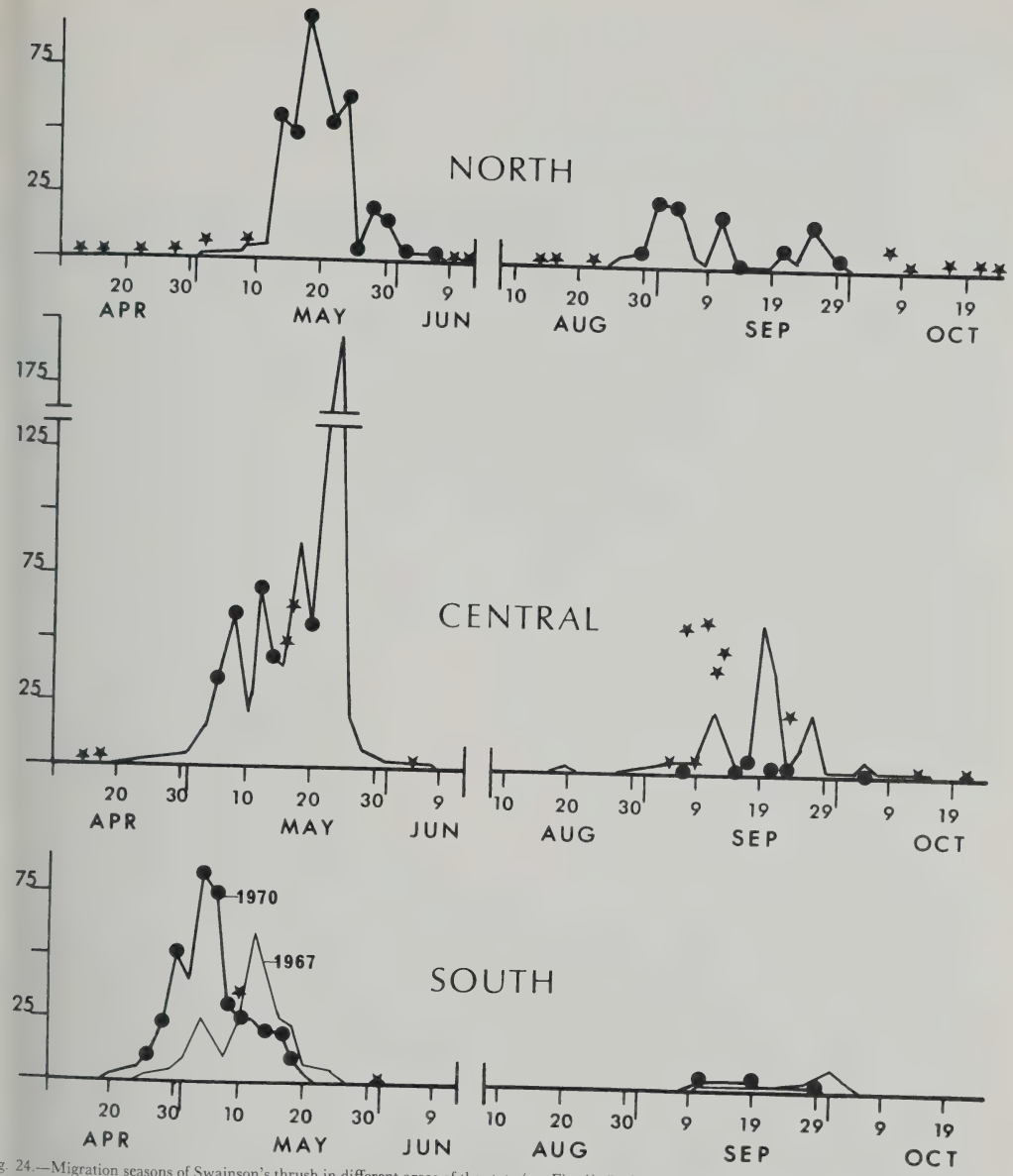
reach southern Illinois in the fall are almost 2 weeks later, in early September (Fig. 24).

Most of the Swainson's thrush population passes through Illinois in September, with peak numbers in the north probably in early September, and in central and southern Illinois in mid-September to late September. Small numbers are found until mid-October throughout the state. A few may linger into November (Ford 1956), but winter records (Ford 1956, Ridgway 1889, and Norton & Spitzer 1965) are accidental or erroneous.

During their night migrations, Swainson's thrushes are among the most common casualties at television towers. There is good correlation of dates between our highest census counts and the highest kills in central Illinois (Fig. 24 and 25). As in the spring, the lowest counts of Swainson's thrushes in the fall were in the south. The tower kill data for Cape Girardeau, Missouri on the Mississippi River also indicate that fewer thrushes migrate through southern Illinois. Paul Heye (mimeographed report) found the tember kills of migrants there to be generally lower those in central Illinois, and the percentage of thrush be much lower (1 percent, versus 14 percent in centra nois).

In our censuses, the fall counts of Swainson's and *Catharus* thrushes were consistently much below tho spring. This is contradictory to expectations, and a the findings of Annan (1962) whose graphs for nortl ern Illinois just as consistently show much higher po tions in the fall. His data show a ratio of 1 bird i spring to 11 in the fall, versus our counts for the n which show 4 birds in the spring to 1 in the fall. Thi serious discrepancy cannot be resolved without bette sus methods.

Our censuses showed the same spring to fall ratio 1) of Swainson's thrushes for east-central Illinoi northern Illinois, but very different ratios for west-c



g. 24.—Migration seasons of Swainson's thrush in different areas of the state (see Fig. 1). Spring and fall graph lines (1967–1970) show the high-y count of each 2 days. Star symbols represent counts made in other years or by other observers. Dot symbols represent counts made on the western he state; lines without dots represent the eastern side.

s (34 in the spring to 1 in the fall) and southern Illi-14 in the spring to 1 in the fall). The paucity of fall nts in west-central Illinois is a phenomenon which we many species.

There are no published banding data to show destinations of Swainson's thrushes that pass through Illinois. Our only record was a bird banded at Almirante, Panama about 2,000 miles south-southeast of Illinois on October 13, 1965

and killed at a television tower near Monticello, Illinois the night of September 20–21, 1966.

Food Habits

Forbes (1903) examined six specimens of Swainson's thrushes taken in central and northern Illinois in April and May, and five taken in September in extreme southern Illinois. He found the Swainson's thrush to have the highest consumption of insects (98 percent of the diet) of any of the thrushes in the spring. Hymenoptera (31 percent of all food, mainly ants) were a primary food, and the intake of Coleoptera (30 percent) was typically high for thrushes. Caterpillars (22 percent) were also very important.

In the fall the diet was changed greatly, with wild fruit (grapes especially, plus cherries, elderberries, and blackberries) making up 60 percent of the food. Gault (unpublished notes, 1906–1918) frequently observed Swainson's thrushes eating elderberries in the north, as we have also in all parts of the state, but if they have a choice the birds will take pokeberries before elderberries. We have also seen these thrushes feeding on the fruit of Virginia creeper (*Parthenocissus quinquefolia*).

Specimen Data

From the large September and October kills of Swainson's thrushes at television towers in central Illinois, we measured and closely examined nearly 300 specimens and saved 93 as study skins. Most of the birds can be placed into three fairly distinct color types with no size differences. About 16 percent cannot be thus segregated. Each type is represented in all sex and age groups.

About 26 percent of all specimens are definitely gray backed (versus reddish) with gray (versus buffy) faces, indistinct spectacles, and dark lead-gray flanks. We believe these birds represent the western race, *incana*.

Another 24 percent of the specimens are gray backed but less gray than *incana*, with very rich buff faces and dark olive-gray flanks. In face and ventral coloration these specimens match birds from the range of the nominate race, but they are much too gray backed. If the group does represent a distinct population we cannot identify it. Dr. Earl Godfrey of the National Museum of Canada examined a few specimens of each of the color types and felt that this group was best considered a color variant of the eastern population *swainsoni*.

Specimens in the third group (34 percent) are definitely

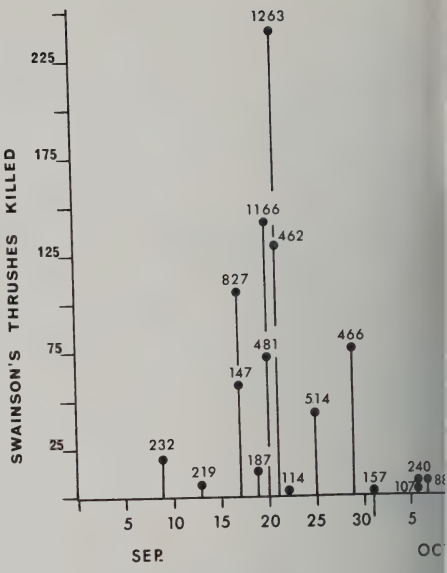


Fig. 25.—Numbers of Swainson's thrushes killed at central television towers during night migration. The numbers on the grap indicate the total numbers of specimens of all species picked up.

swainsoni, with reddish backs, distinct spectacles, buff faces, and pale gray flanks.

Bond (1963) also believed there was a strong mig of western birds (which he identified as *almae*) throug nois. For the present, precise allocation of specimens population or the other is less important than the ne further corroboration, particularly through bandin some western population is an important constituent Illinois fauna. The definite westward flights of telem Swainson's thrushes in the spring (Cochran et al. 1 further indication of the presence of western birds.

The sex ratio in the sample of specimens was even for adults (Table 4), but immature males ou bered immature females about two to one. The age (three adult males to one immature male, and six females to one immature female) do not indicate hig ductivity. Annan (1962) said that immatures g outnumbered adults, but gave no precise figures. T also gives weights and measurements of the specimer

TABLE 4.—Weights and measurements of Swainson's thrushes killed at television towers in central Illinois in September and ber, mainly since 1966.

Age and Sex	Number of Specimens	Gross Weight (grams)		Wing Length (mm)		Tail Length
		Range	Mean	Range	Mean	Range
Adult male	119	27.8–42.0	32.7	95–105	100.1	66–77
Immature male	41	28.4–43.0	33.5	93–102	97.7	63–73
Adult female	118	26.0–36.8	30.3	91–99	95.3	63–74
Immature female	19	27.8–35.9	31.6	90–99	93.4	60–68

RAY-CHEEKED THRUSH (*Catharus minimus*)

(Fig. 26 and 27)

ring Migration

The spring migration of the gray cheek is similar to t of Swainson's thrush (Fig. 24 and 28). Both species nerally begin to appear in late April and become common in early May. Records for northern Illinois on April 2 (Bartel & Reuss 1932, and Bartel 1935*a*) are abnormal. Even records prior to April 20 are exceptional. By May 30 nearly all of the gray-cheek population has passed north of the state (Fig. 28). In the south, arrivals around April 20 are expected, and the population is virtually through the south by May 20. A specimen (Southern Illinois University

g. 26.—Gray-cheeked thrush. (Similar in color to the Swainson's thrush, but without "spectacles" or buffy face.)

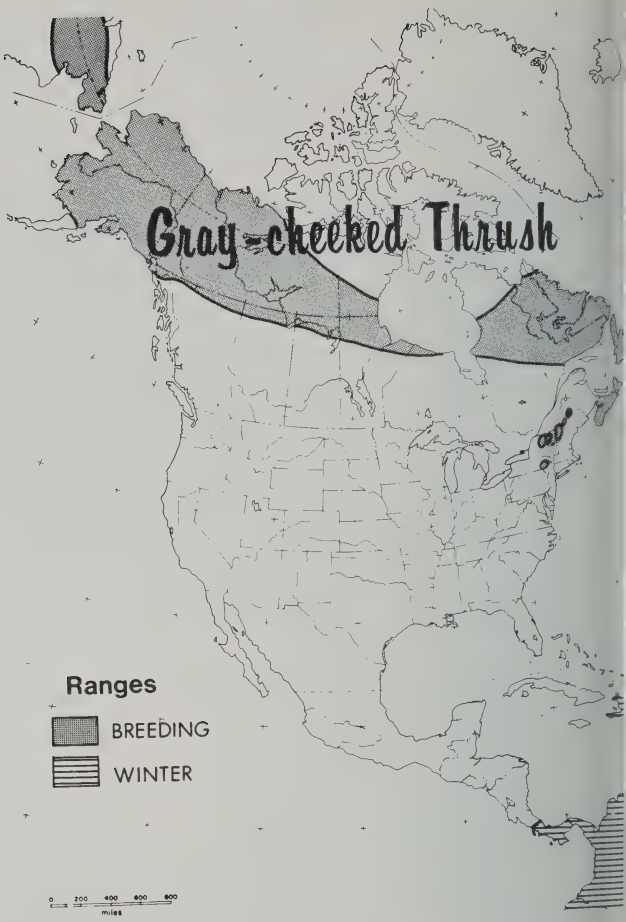


Fig. 27.—General distribution of the gray-cheeked thrush.

collections) taken June 10 in southern Illinois must be considered accidental.

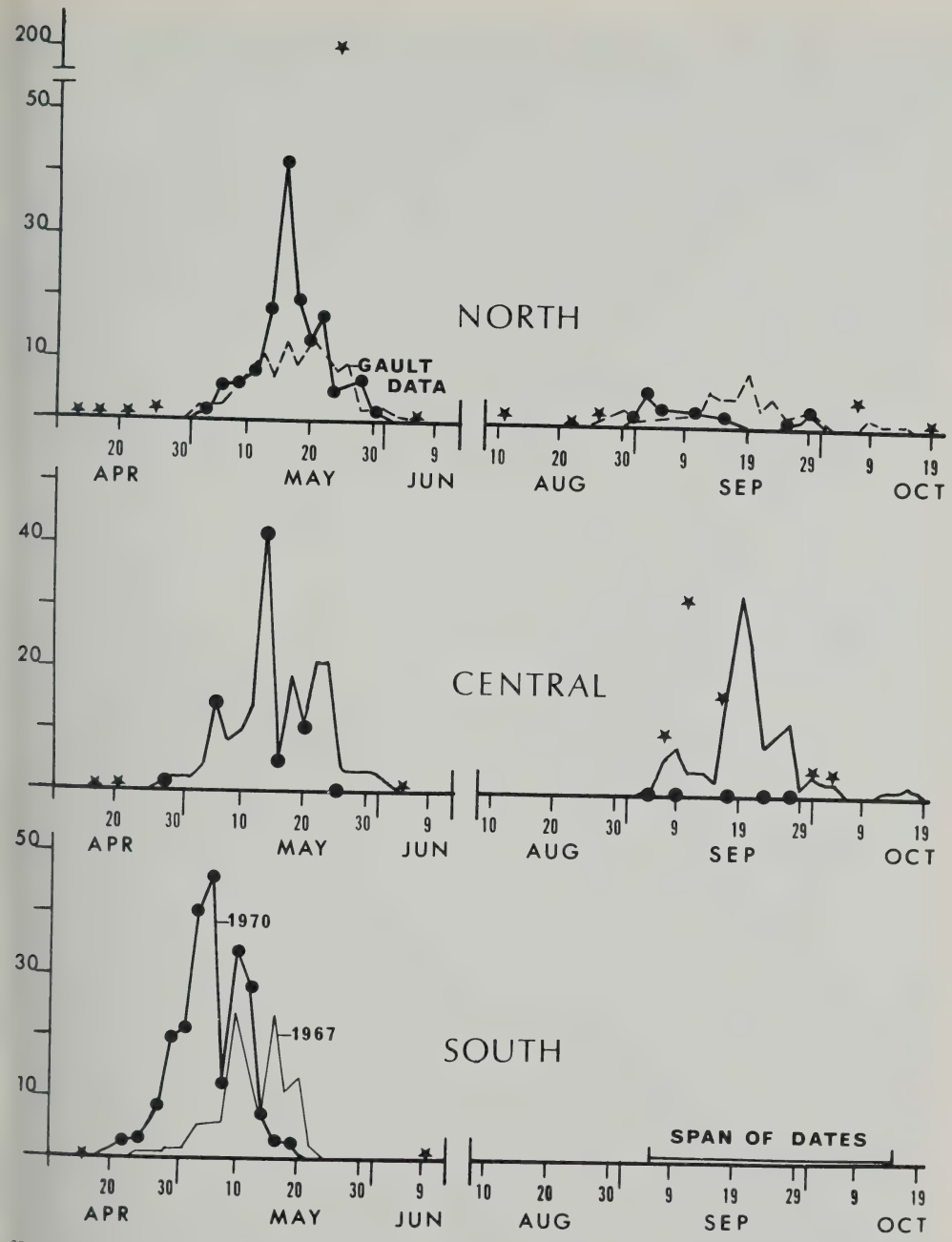
Spring numbers of gray-cheeked thrushes show a fairly uniform distribution through the state (Fig. 28), but phenomenal aggregations have been recorded in northeastern Illinois especially (Eifrig 1913, and Lewis 1923). Eifrig saw hundreds of gray cheeks in late May and felt that Du Page County was on a major "highway" for the species.

Gray-cheeked thrushes sing as they pass through Illinois, but their song is much more subdued than the song of Swainson's thrushes, and in general gray cheeks appear to be less vociferous. Nelson (1876–1877) noticed that gray-cheeked thrushes are more likely to sing at times of misty weather. We translate the call notes most often given as "peeeur" and "peee-oort," but occasionally gray cheeks also call "whit," a note much more characteristic of the Swainson's thrush. We cannot differentiate, with certainty, the migration calls of gray cheeks and veeries. The piercing calls are uttered both at night, during activ ration, and during the day, when the birds are groun

There are no published band recoveries of Illinoi sients, but telemetered gray cheeks have tended to fly ly east of north from Champaign (Cochran et al. 196

Fall Migration

In nearly 50 years of observations, Benjamin earliest fall record for the gray cheek in northeaste nois was August 11, an abnormal arrival date. Usua first gray cheeks do not reach northern Illinois unt August 20, and most of the population has passed Illinois by the end of September, though a few found almost every year until mid-October (Fig. extreme southern Illinois the species is consistently mon in fall. We have no records of more than one s



. 28.—Migration seasons of gray-cheeked thrush in different areas of the state (see Fig. 1). Spring and fall graph lines (1967–1970) show the laily count of each 2 days. Star symbols represent counts made in other years, or by other observers. Dot symbols represent counts made in west-llinois; lines without dots represent the east. Dashed graph line (north) represents the cumulative counts of birds made by Benjamin T. Gault 1875 and 1927 mainly in Du Page County, and shows the long-term peaks and range of migration dates.

day, but gray cheeks have been recorded from September 6 to October 15 in the south (George 1968, and U.S. National Museum specimen).

We have found the fall population to be generally thin, except in east-central Illinois, where we regularly see gray-cheeked thrushes in numbers (Fig. 28). Our data on spring-fall ratios of this species, as in the case of the Swainson's thrush, contrast with those of Annan (1962). Burtis Wilson (Hodges 1954) also noted that gray-cheek populations were much smaller in the fall than in the spring. In the north, we saw 12 gray cheeks in the spring for every 1 seen in the fall. In east-central Illinois the ratio was 2 to 1, in west-central Illinois it was a remarkable 125 to 1, and in the south it was even more lopsided—more than 400 in the spring to 1 in the fall.

Gray-cheeked thrushes, like Swainson's thrushes, are common fall victims of television towers. About 11 percent of all birds killed at central Illinois towers have been gray cheeks. The largest kills occurred between September 16 and 25, which is also the period of our highest fall counts (Fig. 28).

Food Habits

Forbes (1903) examined 10 gray-cheek specimens taken in May. The locality was not given. In its spring insect consumption (93 percent of the diet), the gray-cheeked thrush was second only to the Swainson's thrush, but the most distinctive feature of the gray cheek's diet was that ants constituted almost half the food. No other thrush approached that intake. Caterpillars (15 percent) were typically prominent in the diet as were crane flies and their larvae (9 percent), but gray cheeks took fewer Coleoptera (18 percent), especially Carabidae, than other thrushes. Grasshoppers (3 percent), Myriapoda (2 percent), and molluscs (5 percent) made up the rest of the food. The intake of molluscs, notably *Succinea* and *Helix,* was high for a thrush.

There have been no studies of the food in fall. Gault (unpublished notes, 1917) saw gray cheeks eating elderberries in October, and we have often seen them eating pokeberries in September and October.

Specimen Data

From the kills of gray-cheeked thrushes at television towers we preserved 265 as study skins. As described by Wallace (1939), two color phases are apparent. Our s shows complete gradation from brownish to grayish tremes.

In size the gray cheeks vary according to sex an (Table 5). One adult male and one adult female fell w the size range of the smaller southeastern form, *bic* (Wallace 1939), but statistically both were near the ble extreme limits of normal distribution for our sa There is also the possibility that both specimens we tually immatures which had lost all marks of immat Because of these considerations, we assigned all of th nois specimens we have examined to the northern *minima.* Thus although the alleged occurrence of *bic* in Illinois (see Ford 1956) is doubtful, the final a depends upon other types of investigations such as ba operations, telemetry observations, and biochemica dies.

The age ratios in our specimens, less than one immatures, (Table 5) do not indicate high productivit the sample may not be representative of the species.

VEERY (*Catharus fuscescens*)

(Fig. 29 and 30)

Spring Migration

The veery's spring migration coincides very with the migration of the gray-cheek and Swai thrushes (Fig. 24, 28, and 31). The first veeries appear around April 20 in southern Illinois and Apri the north. Arrivals earlier than April 18 are unusual cially in central and northern Illinois, and reco March and early April (Sanborn 1935, Abbott et al Sparks 1905, and Walter & Walter 1904) are accide erroneous.

Most of the veery population has passed southe nois by May 20, and the north by May 30 (Fig. 31 thin population remains in certain areas of northe nois to nest. The spring veery populations appea fairly uniformly distributed in the state.

The migration calls of the veery are very mu those of the gray-cheeked thrush. Our phonetics calls are "peee-oort" or "wheee-ur" with emphasis first syllable. The calls are uttered both night a

TABLE 5.—Weights and measurements of gray-cheeked thrush specimens killed at television towers in central Illinois in Sep and October, mainly since 1966.

Age and Sex	Number of Specimens	Gross Weight (grams)		Wing Length (mm)		Tail Leng
		Range	Mean	Range	Mean	Range
Adult male	97	29.2–39.3	33.8	96–108	102.8	66–78
Immature male	38	29.5–39.9	34.3	95–105	100.6	63–75
Adult female	86	25.3–38.3	31.4	94–105	98.1	61–72
Immature female	44	28.3–40.3	32.8	92–102	96.2	56–71

Fig. 29—Veery, the least heavily spotted of the Illinois *Catharus* thrushes. (With reddish back).

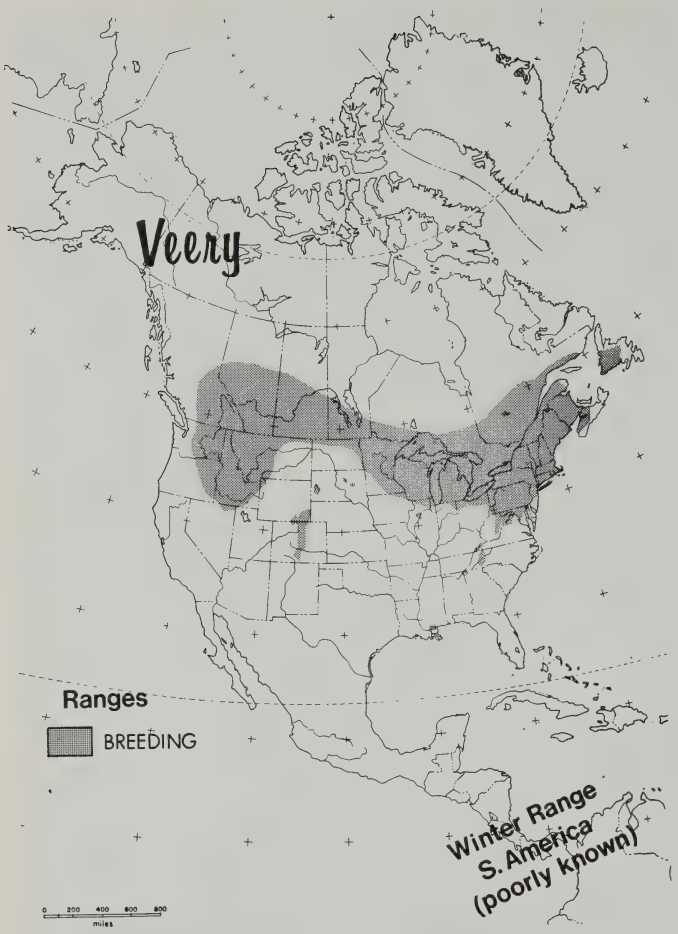


Fig. 30.—General distribution of the veery.

Transient veeries also sing, but the song is not heard as often as the songs of Swainson's or gray-cheeked thrushes.

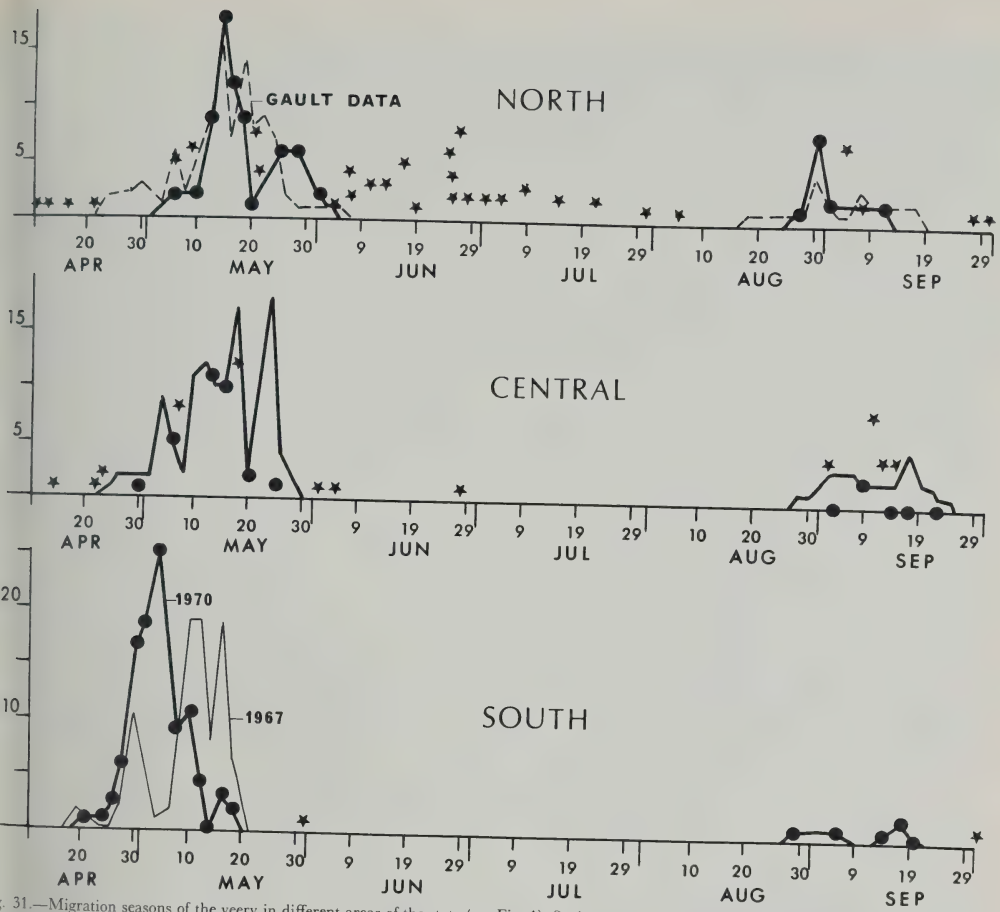
Distribution

The general distribution of the veery is shown in Fig. 30. The nesting distribution in Illinois (Fig. 32) is still poorly known, and only a few students have actually found nests (Cooke 1888, Pratt 1890, Ford 1956, and Thompson 1958). The two central Illinois records (Fig. 32), one an alleged dropped egg (Barnes 1890), and the other a singing male in Peoria in late June (Silloway 1922), are questionable as actual breeding records. Observers should look for the species in the summer throughout northern and central Illinois.

Two types of habitat have been recorded in Illinois. In areas of Winnebago county, Lee Johnson (personal communication) has found nesting veeries in mature bottomland forest. The species has also been recorded in residential habitat (Pratt 1890, and Farwell 1919). field (1951) reported the best nesting habitat in I and Ohio to be sandy hillocks interspersed with bo nesting veeries should be looked for in the Illinois areas also.

Fall Migration

Alfred Reuss (personal communication) has not the breeding population of veeries in northeastern becomes very inconspicuous in August, following the al pattern of other nesting species. The definite inc veeries in late August is indicative of migration as t cies also appears then in central and southern Illinc 31). An August 13 record for extreme southern (Gower 1933) is probably erroneous. The veery's gration is less prolonged than the migration period



31.—Migration seasons of the veery in different areas of the state (see Fig. 1). Spring and fall graph lines (1967–1970) show the highest daily each 2 days. Star symbols represent counts made in other years or by other observers. Dot symbols represent counts made in west-central Illinois; hout dots represent the east. Dashed graph line (north) represents the cumulative counts of birds made by Benjamin T. Gault between 1875 and inly in Du Page County, and shows the long-term peaks and range of migration dates.

heek and Swainson's thrushes. Most of the veery tion is through Illinois by September 20. There are October records, the latest being October 13 for the Ford 1956), and our specimen from a central Illinois on tower, killed the night of October 8–9, 1968.

with the gray-cheeked thrush, we saw few veeries in in comparison with spring (Fig. 31). This was also perience of William Dreuth (Clark & Nice 1950), njamin Gault (Fig. 31). In northern and central Illi- saw 6–7 veeries in the spring to every 1 in the fall, he south the ratio was about 20 to 1.

eries are less common than Swainson's and gray- l thrushes in Illinois, and this population difference cted in the tower kills (Graber 1968). Only about 1 of the birds killed at central Illinois television tow- eptember were veeries.

Specimen Data

We have examined 41 fall and 34 spring specimens of veeries from Illinois, but no Illinois breeding specimens. Among the migrants there are two color extremes, red and grayish, with virtually complete color intergradation and no consistent size difference between the two. The gray specimens well match even the extreme gray specimens from the range of the western race *Catharus fuscescens salicicola,* and the red specimens are similar to specimens from the range of the eastern race *C. f. fuscescens.* There are few specimens of the eastern race from Illinois, while *salicicola* is well represented. In the fall probably all specimens are best ascribed to *salicicola,* with about 5 percent showing intermediacy towards *fuscescens.* In the spring most of the birds are *salicicola,* but about one-third are of the eastern form.

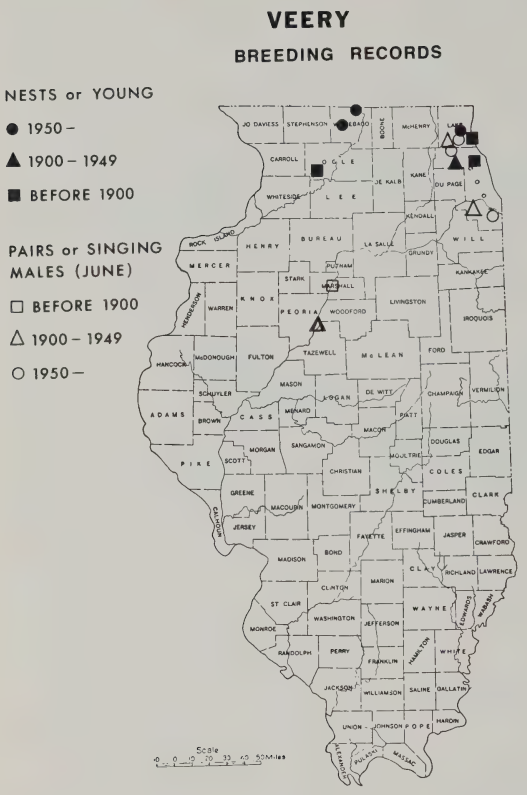


Fig. 32.—Breeding records for the veery in Illinois. Singing male records are for June only.

EASTERN BLUEBIRD *(Sialia sialis)*

(Fig. 33 and 34)

Spring Migration

Though there are winter records of the bluebird for all regions of the state, and there is a sizable winter population in southern Illinois, the migrations are conspicuous (Fig. 35). The arrival dates most often given are around February 20 for central Illinois and February 26 for the north. Arrivals in early February are apparently infrequent in both regions, but in some years bluebirds are common in central Illinois even in January (Musselman 1933, 1934–1935, and 1939), with groups of 30 or more being seen.

The largest numbers of bluebirds in the spring have been recorded in March, and most of the migration probably occurs in that month (Fig. 35). Zimmer (1922) observed "hundreds" near Rock Island on February 22, but noted that such aggregations were unusual. Populations in the spring, as well as in other seasons, are highest in sc ern Illinois.

Judging from the literature, the actual migration fl are rarely witnessed. Van Duzer (1922) and Schafer (1 recorded diurnal flights, possibly migrations, in nort Illinois in late February and in March. We have definite diurnal migrations of bluebirds only in the (Fig. 35). There is no evidence of nocturnal migration, as nightcalls and television tower kills, as there is for thrushes.

Distribution

The general distribution of the bluebird is show Fig. 34. The available breeding records for Illinois 36) do not truly indicate the state distribution. Large in the state, especially intensively cultivated tracts, a sentially devoid of bluebirds. We estimated that 80 pe of the Illinois bluebird population was in the southern of the state (Graber & Graber 1963).

Nesting Habitats and Populations

The bluebird's usual habitat includes woody vege in or adjacent to open fields, especially grasslands, treeless areas, even where nesting boxes have been p ed, are unlikely to have significant bluebird popula Large blocks of forest are also poor for the species (V 1964), though forest edge supports low population (Table 6). Residential habitat was more important bluebird prior to 1900, but the species has been dis by house sparrows and wrens (Nehrling 1880, Ri 1915).

The earliest successional stages of forest are not su for bluebirds (Brewer 1958, and Karr 1968). In so Illinois Brewer found no bluebirds in strip-mined that had been abandoned about 14 years.

Bluebird habitats must have suitable nesting c and the elimination of rail fences and wooden fenc has had a detrimental effect on the bluebird popu (Musselman 1940). Bluebirds seem to have undergo transitions with regard to nesting sites in the pa years. Many of the early references (before 1900) nests in cavities of dead trees, stumps, or the dead br of cottonwoods (*Populus*), willows (*Salix*), or orcha (Gault, unpublished notes, 1876–1889; and Louc published notes, 1888). From dead trees to fence po a natural transition, and most of the nests recorded literature were in fence posts until recent years, esp since 1950, when most of the records have been fr boxes. Bluebird nesting box routes like those establi Musselman (1944), and Varner (1964) are now p important to the species. There are no data on the bility of natural cavities.

Bluebird nests in natural cavities have been reco low as 1½ feet above ground and as high as 11 feet have undoubtedly been much higher nests, but m ords, even for natural sites, are below 7 feet.

The only territory measurement we have seen

33.—Bluebird carrying food near a nest box, in Pope County, Illinois.

d in Illinois is that of Fawver (1947*a*), 3.5 acres. man (1935) noted that bluebirds did not nest closer than one-fourth of a mile in west-central Illinois, tel (Smith & DuMont 1944) effected a 40 percent in a bluebird population near Blue Island when he d the number of nest boxes from 10 to 27 in a one- e square area. In the south we have found contem- us nests as close together as 380 feet.

Major periodic crashes in the bluebird population (Fig. 37) is a phenomenon of long standing. Butler (1896) noted a sharp decline in northern Illinois and Indiana in 1895 and attributed it to severe cold in April. Later studies have also indicated that such crashes are, to a large degree, correlated with adverse weather, especially in the winter and spring (Barnes 1912, Musselman 1941, and James 1960). Musselman (1941*a*) estimated that 50 percent of the blue-

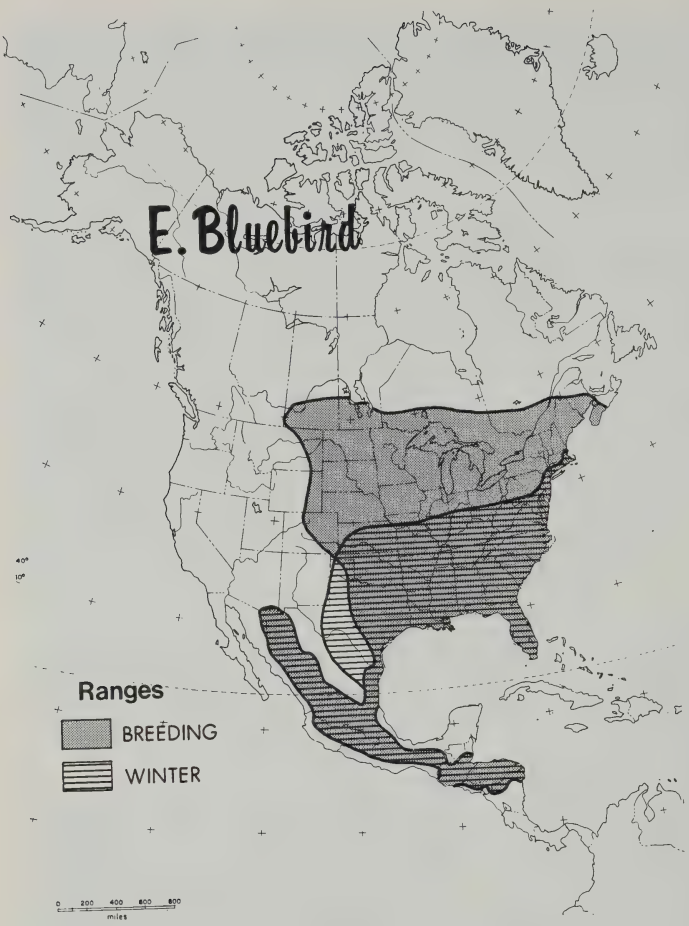


Fig. 34.—General distribution of the bluebird.

bird population in west-central Illinois succumbed to cold and snow one spring. In Tennessee, which is part of the bluebird's winter range, Laskey (1958) found many dead bluebirds that had been roosting in nest boxes (as many as 12 dead in one box) after severe cold and snow in mid-February. We have also found dead bluebirds in roosting cavities in February in southern Illinois, and Musselman (Peterson 1965) found dead birds in his nest boxes in April.

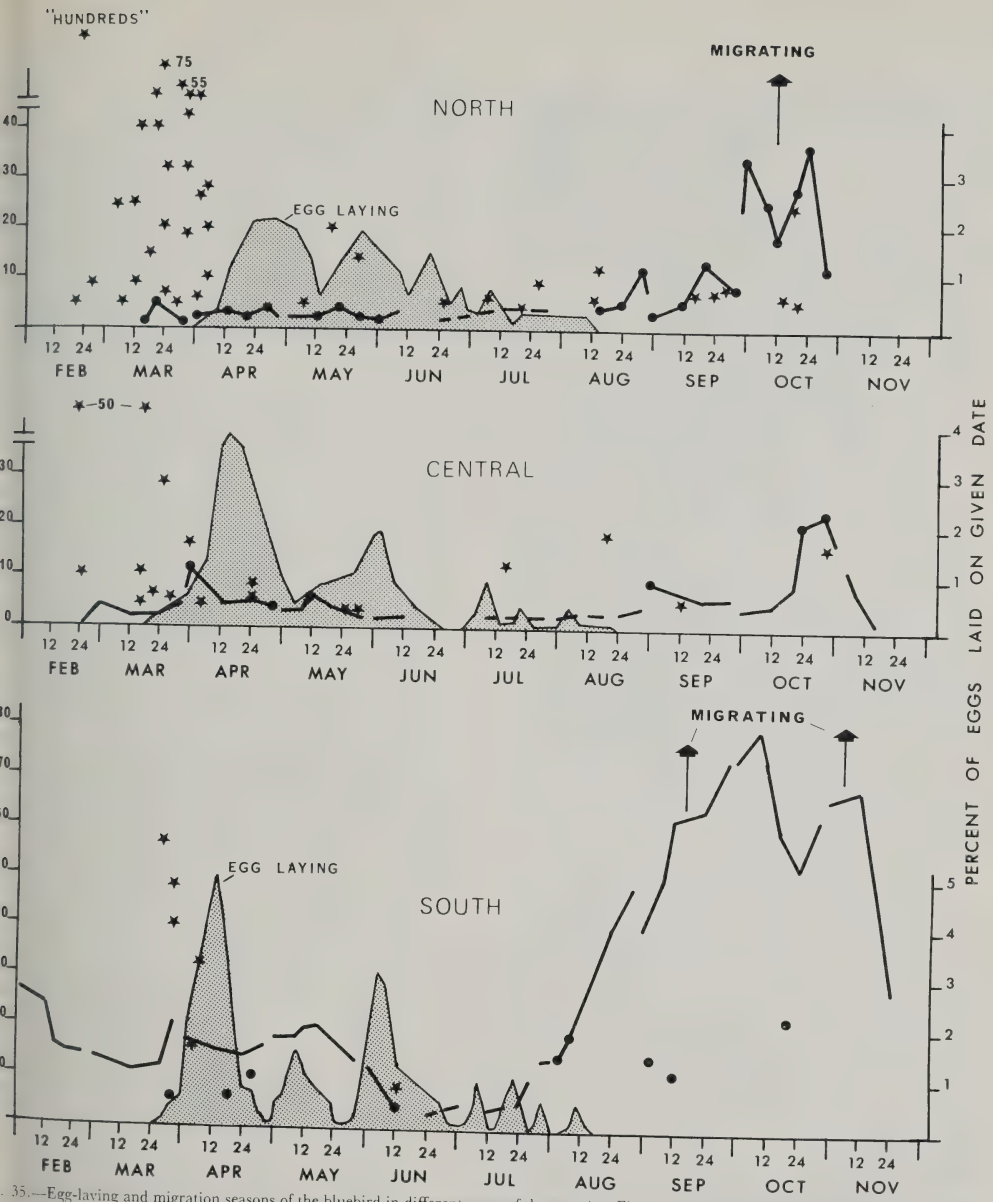
Nesting Cycle

Banding returns reported by Bartel (1950, 1952), Holcombe (1930, 1932), and Musselman (1934) show that some young bluebirds as well as adults return to the areas of their birth and the adults sometimes return to the same box. However, no quantitative data have been published to show what part of the population returns. Musselman (1934) felt that young birds tended to scatter more.

There is little reference to the bluebird's song in t nois literature, and nearly every mention of the son to the month of March as the time of singing. Ri (1889) indicated that there was a resurgence of s song in August, but the periodicity of singing has n recorded in any systematic way.

The earliest nest with eggs for Illinois was r March 20 by Musselman (1937) in central Illinois is no indication that nesting begins earlier in the sou 35). The laying curves for the bluebird have severa The first peak occurs in April throughout the sta about a 12-day lag in the north (Fig. 35). There laying peaks in May and June, and though a few n established as late as mid-August, laying is largely the end of June.

Musselman's work with banded birds show bluebirds tend to have two broods in one season. T pair of bluebirds may use the same box for two con



35.—Egg-laying and migration seasons of the bluebird in different areas of the state (see Fig. 1). Spring and fall graph lines (1967–1970) show est daily count of each 4 days (left scale). The lines are interrupted where data have not been collected. Star symbols represent counts made in oth- or by other observers, mainly before 1930. Dot symbols represent counts made on the western side of the state; lines without dots represent the ide. Shaded areas show the percent of eggs laid on a given date (right scale). Arrow symbols indicate dates of actual migration flights.

(Holcombe 1930), females also often change houses en nestings, sometimes moving miles away elman 1946). Some boxes have four sets of eggs in a (DuMont & Smith 1945), but not necessarily from ne pair. References to three broods by the same pair have apparently not been substantiated by observations of banded birds.

The April laying peaks are much higher than the subsequent peaks (Fig. 35), and data on nest-box occupancy show the same trend. During several years and in different

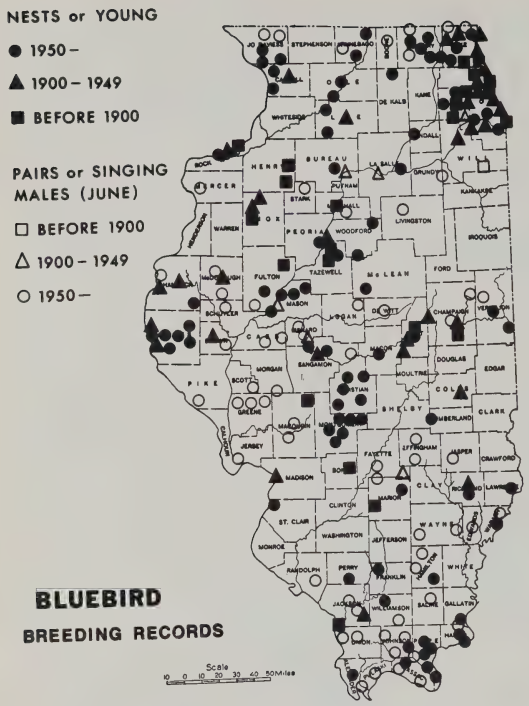


Fig. 36.—Breeding records for the eastern bluebird in Illinois. Singing male records are for June only.

areas in west-central Illinois, occupancy of houses by b birds fell about 23 percent between the first (April May) and second (June and July) nestings, with the tremes in different years being as low as 8 percent an high as 66 percent (based on data from Musselman 1 1936, and Evers 1937). Bartel (DuMont 1947) recorde exceptionally high rate (90 percent) of "second-nest occupancy in 1947 at Blue Island. There are no comp tive data for the south.

The bluebird appears to have a prolonged nesting The full cycle for one nest observed in central Illinois, nest-building to fledging of young, required 47 days (S 1939), but this was an early nest, started April 5, and building was slow (12 days). Nests have been buil days or less (Musselman 1934–1935, and Varner 1 We have recorded nest-building periods of 6 and 7 da southern and central Illinois, with incubation perio 13–15 days (most frequently 14 days), and nestling pe of 15–17 days (most often 16 days). Holcombe's (observations in the north also indicated an incubation od of 14 days, and nestling period of 16 days. Thus, cycle, including egg laying for a nest with five eggs m expected to take about 40 days.

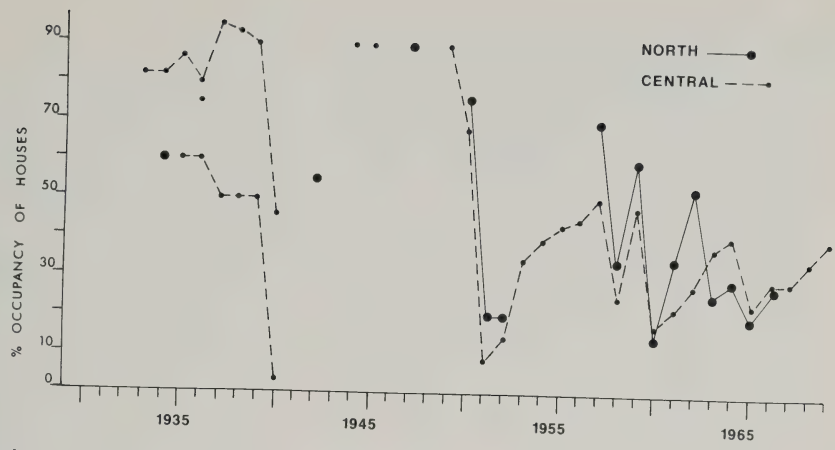
Throughout the state, most nests receive 5 eggs f first nesting, but clutch size declines in later nests, esp ly in the south (Table 7). Among the hundreds of ne observed Musselman (1946*a*) once recorded a clutch en eggs, and once nine eggs in one nest, contributed b females.

The eggs are generally pale blue, but sometimes and rarely are both types found in the same nest. In h tensive studies in west-central Illinois Musselman 1946) found about 5–6 percent of the eggs to be white

TABLE 6.—Breeding populations of bluebirds in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Orchard	5	80	1936	Nest	Lake (N)	Beecher 1942
Edge shrubbery	9	34	1957	Strip	South	Graber & Graber 19
Block shrub areas	67	1	1957	Strip	South	Graber & Graber 19
Late shrub	..	10	1966	Nest	Vermilion (C)	Karr 1968
Thicket	13	1	1950	Nest	Jackson (S)	Brewer & Hardy 19
Residential	8	25	1916	Nest	Richland (S)	Cooke 1916
Parkland estate	100	12	1915	Nest	Cook (N)	Eifrig 1915
Unmodified woods	27	15	1936	Nest	Lake (N)	Beecher 1942
Forest (all types including edge)	79 174	1 2	1957	Strip	North South	Graber & Graber 19
Forest edge	55	(0–2 per mile)	1927–1970	Nest	Champaign (C)	Kendeigh 1948, Kendeigh & Clemat
Second growth or cut-over woods	15	13	1937–1938	Nest	Rock Island (N)	Fawks 1937, 1938
Grazed bottomland	93	4	1955	Nest	Macon (C)	Chaniot & Kirby 19
Pastureland	147 54 72	3 2 8	1957	Strip	North Central South	Graber & Graber 1

[a] All figures were converted to read birds per 100 acres or birds per mile of edge (number of territorial males or nests x 2).



ig. 37.—Annual on in nest box occu- by bluebirds for sev- outes in central and rn Illinois. Two cen- linois routes showed me population crash 0, and there was a l similarity in the tion trends in north- l central Illinois.

he incidence of cowbird parasitism of bluebird nests is Musselman 1942). The rate was exceptionally high e species in 1945, 7 nests parasitized out of 268, or 3 percent (Musselman 1946).

here are no extensive data on nesting success for pop- ns in either the north or south. Duncan's -1935) small sample of nests in Cook County indicat- lging success of 50 percent of the eggs. Our data for uth, representing 51 nests, showed fledging success of rcent in April and May, and 54 percent for June to t eggs.

sting success for the bluebird seems to depend a great n weather factors. Evers (1937), in west-central Illi- ound fledging success of about 90 percent of the eggs first nesting (April and May), but success of second gs was down to 50 percent. He attributed the reduced to very high late-summer temperatures (114° F. in de). In a 7-year period Musselman (1939*a*) recorded evere April freezes that froze many eggs. He has rec- nesting success rates as low as 38 percent and as high ercent of the eggs (Musselman 1935). In general, nestings were less successful than those in April and nfertility varied from 1 percent to 23 percent, with rage of 9 percent, and low hatchability was again

BLE 7.—Clutch sizes of bluebirds in different regions of

Months	Number of Nests	Average Clutch	Percent of Nests by Clutch Size			
			6 Eggs	5 Eggs	4 Eggs	3 Eggs
April–May	64[a]	5.0	16	72	12	0
June–August	57[a]	4.4	2	53	26	19
April–May	169[a]	4.9	15	64	16	4
June–August	127[a]	4.3	2	43	39	16
April–May	15	5.1	13	80	7	0
June–August	18	4.2	0	28	61	11

es records from the literature where complete data were provided.

correlated with severe heat (26 days over 100° F.) and drouth.

Other frequently mentioned sources of nest mortality relate to competition with other species for nesting cavities. Hodges (1953) noted that bluebird populations on Credit Island near Rock Island declined coincidentally with an increase of house wrens (*Troglodytes aedon*) in the area. In other areas of northern and central Illinois bluebirds also fared poorly in competition with wrens for housing (Bartel *fide* Smith & DuMont 1944, and Musselman 1946). Wrens occupied from 2 to about 7 percent of Musselman's nest boxes, and perforated as many as 7 percent of the bluebird eggs some seasons (Musselman 1935). When the bluebird's first nesting was delayed, the population was thrown more directly into competition with the generally later-nesting wren (Musselman 1939).

In extreme southern Illinois we have not observed any interference from house wrens, but wren populations are low there. In northwestern Illinois, on the other hand, in a sample of 33 nest boxes we found 76 percent occupied by wrens in June, versus only 9 percent occupied by bluebirds. In east-central Illinois, Campbell (1970, and personal communication) recorded 9 percent of 23 boxes occupied by wrens, versus 35 percent occupied by bluebirds in 1970, but in 1971 wrens took over most of the boxes.

In human residential areas, bluebirds cannot compete with house sparrows (*Passer domesticus*), and there is competition even in rural areas. In western Illinois house sparrows utilized more nest boxes than did wrens. From data provided by Musselman (1934, 1934*a*, 1935, and personal communication) we calculated the incidence of occupancy for sparrows in rural areas to vary from 1 to 14 percent, with an average of 6 percent. For redheaded woodpeckers (*Melanerpes erythrocephalus*), tufted titmice (*Parus bicolor*), and black-capped chickadees (*Parus atricapillus*), the incidence of occupancy averaged about 5 percent each. Nest boxes in woods and forest edge are more likely to attract chickadees and titmice (Musselman 1935).

In southern Illinois we found Carolina chickadees

(*Parus carolinensis*) occupying from about 10 to about 40 percent of the bluebird boxes, with bluebirds occupying 60 percent of the boxes. We witnessed no aggressive competition. However, in northwestern Illinois Wilson (Hodges 1954) observed that bluebirds and black-capped chickadees were keen competitors. In the same region Schafer (1920) saw redheaded woodpeckers destroy bluebird nests, and we have seen one such incident in the south.

Eifrig (1937) suspected that starlings (*Sturnus vulgaris*) were important competitors of the bluebird (see also Schafer 1932, and Musselman 1934*a*, 1942), but this competition can be eliminated on nesting box routes by proper box design and placement (Varner 1964). Varner also warned that boxes near water tend to be taken over by prothonotary warblers (*Protonotaria citrea*), and tree swallows (*Iridoprocne bicolor*).

Bluebirds also have to compete for cavities with small mammals, notably deer mice (*Peromyscus*) and flying squirrels *(Glaucomys volans)*, and with wasps (Musselman 1934, 1947).

There is little information on other causes of nest loss. Musselman (1946) considered loss from snake predation to be small, but cautioned (1935, 1940) that boxes in brushy or weedy places are particularly susceptible to black snake, shrike, and mouse predation.

Persons who wish to establish bluebird nest-box routes should read Musselman (1941, 1944), Varner (1964), and Kibler (1969) for valuable instructions.

Fall Migration

Our data indicate that most of the fall migration occurs from September into early November in central and southern Illinois (Fig. 35). Our earliest observation of actual migration flights in southern Illinois was September 17 and the latest was November 6, but both these dates probably fall short of the true extremes.

In our experience, bluebird migration was never the massive steady flow of birds as in the case of robins, blue jays, and other diurnal migrants. Bluebirds flew in the morning in small, loose flocks going south and southeast.

Nelson (1876–1877) dated the fall migration in northeastern Illinois from September 12 to October 25, and this closely coincides with the timing of our high census figures for the north (Fig. 35). Schafer (1922) recorded exceptionally large migrations in the north in 1922 nearly every day in September and early October.

The numbers of bluebirds seen in the fall (September into November) consistently exceeded the spring (February through May 10) counts throughout the state. The ratios were one bird in the spring to three in the fall for central Illinois, one to six in the south, and one to eight in the north.

There are very few published band recoveries to indicate destinations of migrating Illinois bluebirds. Birds banded in the spring and summer in northeastern and west-central Illinois have been recovered in the winter from southeastern Texas to southern Louisiana and southern Georgia (Bent 1949, and Musselman 1937).

Winter Records

Bluebirds have been found in all regions of the sta the winter (Fig. 38), but 90 percent or more of the st winter population is in the southern zone (Graber & ber 1963, and Fig. 39). In about one-third of the y there are no bluebirds recorded in the northern and ce Christmas counts (Fig. 39). They are most likely found along major rivers, especially in the northern h the state (Fig. 38). The species is usually found in flocks of 3–20 birds.

The bluebird's population crashes, as discussed Nesting Habitats and Populations above, show up cl in the Christmas counts (Fig. 39), and there is good lation in time between the low breeding population low populations in winter (Fig. 37 and 39).

Our censuses showed pastures and other grassl forest edge, and shrub areas to be favored winter ha (Graber & Graber 1963). The only absolute measure of winter populations are by Shaw & Scherer (1960) Shaw et al. (1964), who censused a shrubby field a southern Illinois and found densities ranging from less one bluebird per 100 acres to seven per 100 acres i year census period.

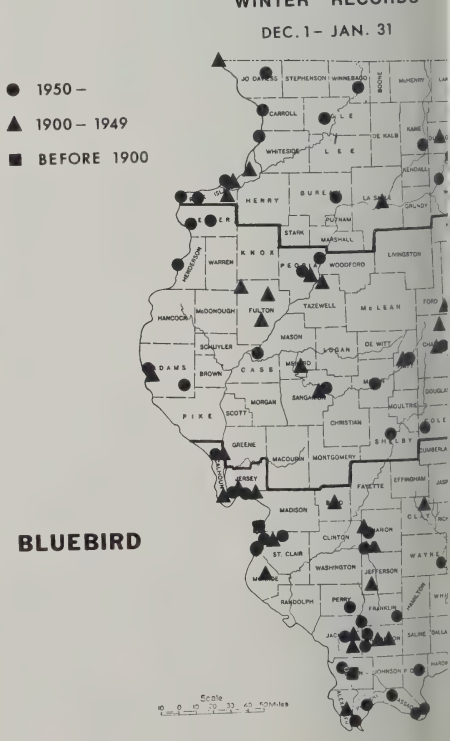
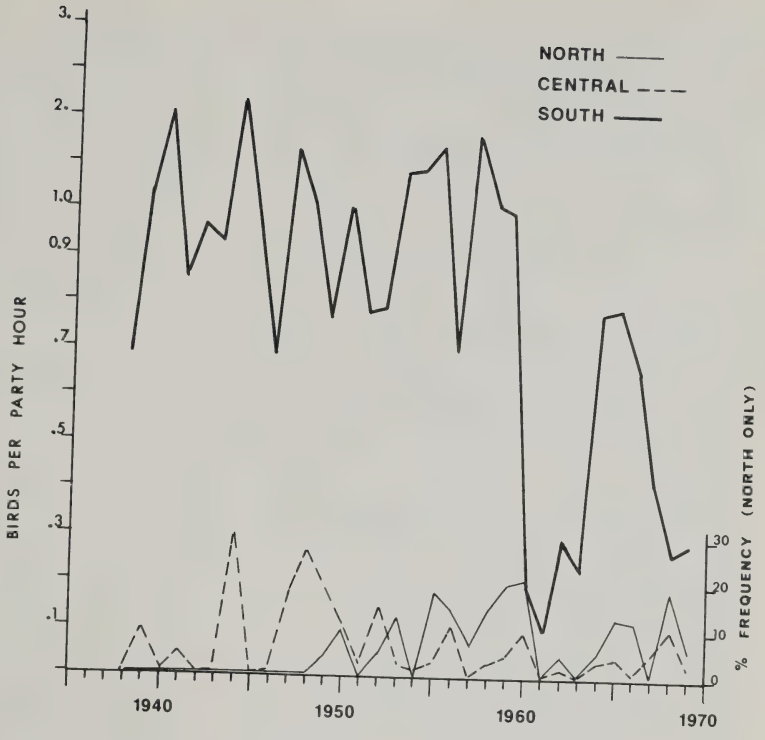


Fig. 38.—Winter records for the eastern bluebird in Illi three regions of the state discussed in the text are shown by heavy



g. 39.—Annual variation in bluebird populations, based lubon Christmas counts in gions of the state. The calcu- or the north (right scale) is cy of occurrence of bluebirds tage of all counts on which ls were seen). The calcula- the central and southern re- number of bluebirds seen per our in the field (left scale). ormation about the Audubon as counts, see Cruickshank

labits

bes' papers (1903) are the only systematic studies on d of bluebirds in Illinois (Fig. 40). His specimens ken in central and northwestern Illinois, except for nber sample taken in extreme southern Illinois. In- mprised a very large part of the diet except in the

ough bluebirds take much of their food from the they often look for prey from an elevated perch. ervation of Cooke (1885) that many bluebirds for- meadows, picking around the roots of grass, is in with the stomach analyses of Forbes, who found ss-eating cutworms were important in the blue- iet. In the spring, cutworms, predaceous beetles, g beetles were the principal prey. Surprisingly, s did not show the marked change to fruit in June ved for the robin and the mimids. In late summer crickets and grasshoppers became very important et as the intake of beetles declined.

e winter, the diet consisted almost entirely of fruit. e was especially prominent, but grapes, sumac, d holly were also important. Link (1940*a*) also holly berries in the December diet, and Cooke so recorded sumac. In northeastern Illinois Nelson 377) observed bluebirds eating the fruit of Virginia

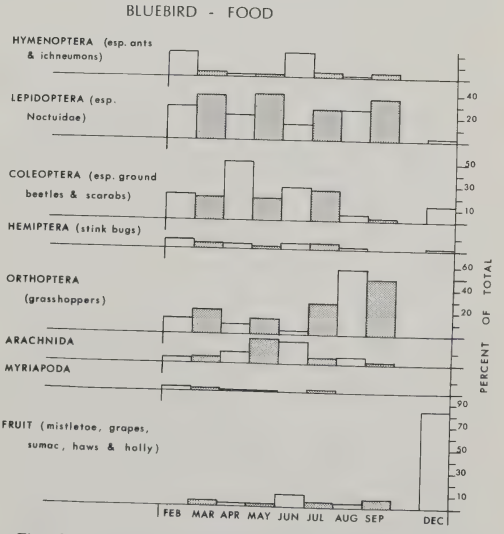


Fig. 40.—Food habits data on the eastern bluebird based on the study of Forbes, 1903 (1880). Percentages represent the part of the total food identified in the stomachs of a number of bluebirds examined each month.

Longevity

There are no quantitative data on life expectancy or survival rates for any bluebird population in Illinois. Bartel (1950) recovered a banded female at least 5 years old.

Mortality factors other than nest mortality and severe weather, as already discussed, are also unrecorded.

MOUNTAIN BLUEBIRD *(Sialia currucoides)*

There is no valid record for the mountain bluebird in Illinois (Cory 1909). Princen's (1970) report is based on an inadequate observation, and is unacceptable.

TOWNSEND'S SOLITAIRE *(Myadestes townsendi)*

There are six records of Townsend's solitaire for Illinois. The species is represented by one specimen taken by Charles Douglas at Waukegan, Illinois, December 16, 1875 (Ford 1956). All occurrences were in the northern part of the state.

Single solitaires have been observed to winter at Morton Arboretum on three occasions, being present from December 27, 1953 to March 28, 1954 (Bartel 1954); from November 23, 1958 through February 1959 (Mumford 1959); and after the Christmas count period of 1959–1960 (Mumford 1960).

The bird collected in 1875 was found feeding on hawthorn fruit *(Crataegus tomentosa)* in a sheltered ravine. In 1954 in Morton Arboretum the solitaire found food in an area of crab apple and hawthorn plantings.

The latest record, in the spring, was a bird seen about 7 miles south of Rock Falls on April 6, 1969 by Max and Ann Hagans (Shaw 1969; and Hagans, personal note).

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ILLINOIS STREAMS:

A Classification Based on Their Fishes and an Analysis of Factors Responsible for Disappearance of Native Species

By Philip W. Smith

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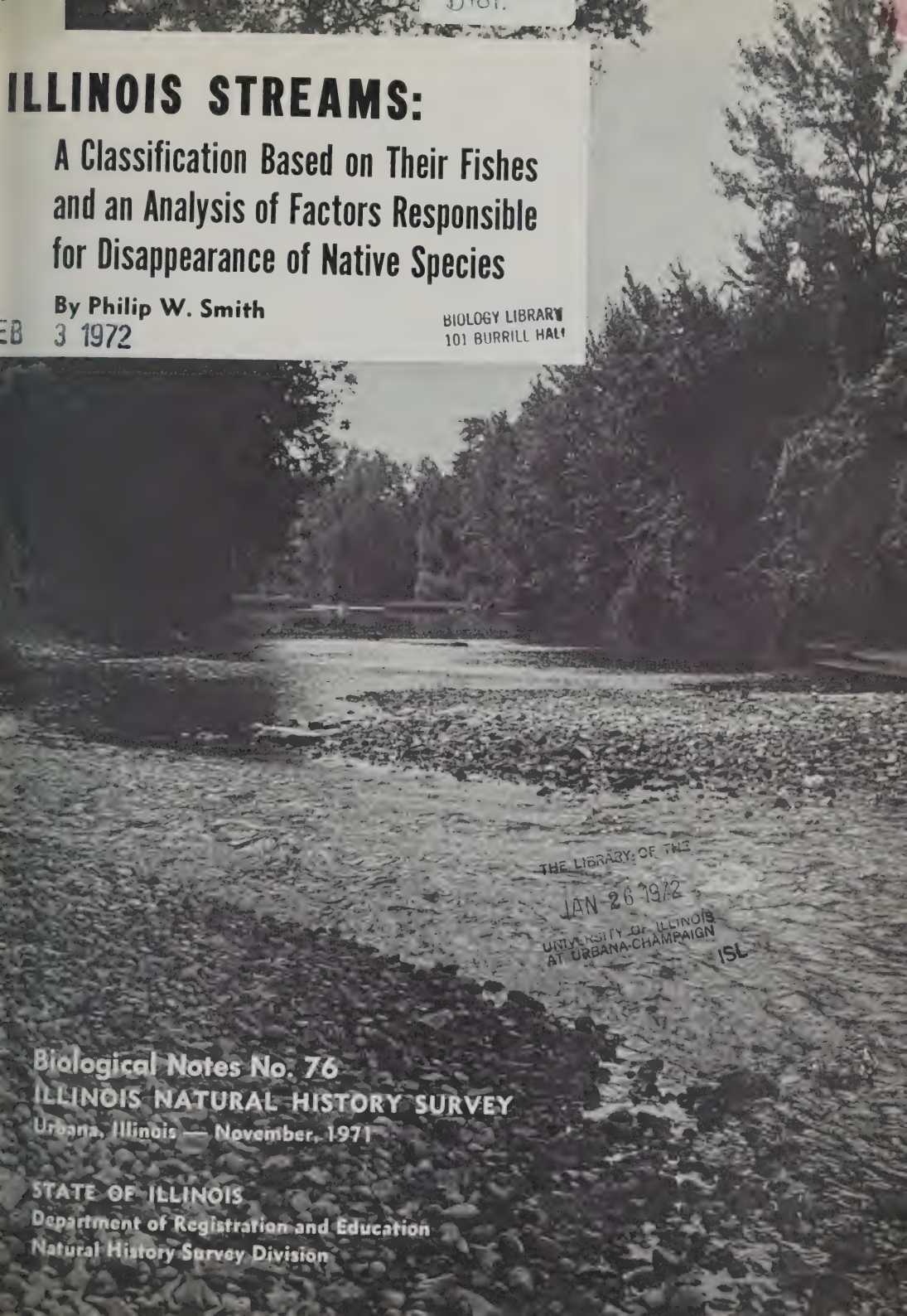

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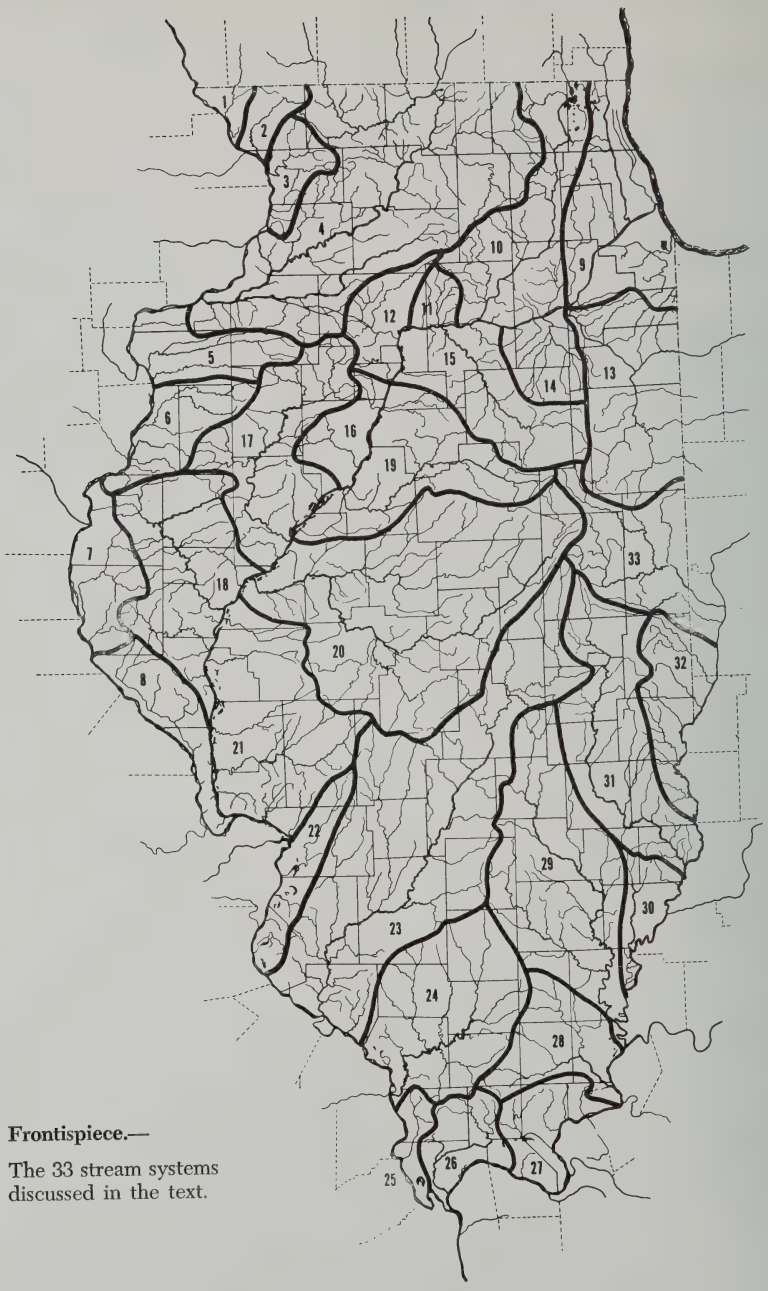

Frontispiece.—

The 33 stream systems discussed in the text.

COVER PHOTO: One of Illinois' finest streams, the Middle Fork of the Vermilion River near Collis Vermilion County. Photo by Lee Trail.

LLINOIS STREAMS: A Classification Based on 'heir Fishes and an Analysis of Factors Responsible or Disappearance of Native Species

Philip W. Smith

ILLINOIS HAS MANY different drainage systems. is bounded on the west, south, and southeast by reat rivers and on the northeast by Lake Michigan. 'ithin its borders it has many creeks, rivers, ponds, ıd artificial lakes, plus a few glacial lakes in the ortheastern corner of the state. Thus it is not surising that almost 200 species of fishes have been corded in the state. The great number of streams ıd variety of stream habitats are primarily responsible r the richness of the Illinois fauna.

As a group, fishes are tolerant and adaptable ornisms that can survive considerable habitat abuse, ıt the ecological tolerances of the many different ecies vary tremendously. The presence of fish indites little about the condition of a stream, but a owledge of the assemblage of species and their merical relationships provides the ichthyologist with excellent biological picture of the water course d its well being. When such information is available er a long period of time, fishes can be one of the ost sensitive indicators of the quality of the aquatic vironment.

From time to time for more than a hundred years, thyologists at the Illinois Natural History Survey d other agencies have conducted censuses of Illinois ies so that, in a sense, changes in the aquatic envi- ıment have been monitored all this time. A particuly thorough collecting program spanned the period m 1876 to 1905 and culminated in publication of classic "Fishes of Illinois" (Forbes & Richardson 08). The collecting stations are shown in Fig. 1. other program, begun in 1950 and recently comted, was even more thorough, thanks to modern nsportation facilities. The collecting stations are wn in Fig. 2. A wealth of information on changes ish populations and aquatic habitats in Illinois has n assembled by comparing distributional patterns census data from the two surveys, and this inmation is available to interested agencies.

Analysis of these data has made it possible to as- virtually all of the streams in the state ratings xcellent, good, fair, or poor. The ratings are based the species composition of the hundreds of collecs available. It has also been possible to detect g-term changes, and to identify factors that are responsible for each stream's deterioration and each species' change of status.

Owen F. Glissendorf, Technical Editor of the Survey, edited the manuscript. Lawrence M. Page aided in the analysis of data and critically read several preliminary drafts of the manuscript. He and R. Weldon Larimore provided counsel in many areas. Douglas W. Schemske compiled the counts of species known from each drainage system by consulting species distribution maps. Since 1962, Alvin C. Lopinot and his staff in the Division of Fisheries of the Illinois Department of Conservation have deposited in the Survey collection hundreds of fish collections made throughout the state. I have made free use of information assembled in the series "Surface Water Resources" for Illinois counties issued by the Division of Fisheries and recommend these publications to anyone interested in more specific detail about his own county.

CLASSIFICATION AND DESCRIPTION OF STREAMS

The following annotated list of stream systems rates each stream on the basis of fishes presently known to occur in it and its potential for harboring others. A rating of excellent signifies that the expected species are still present in a numerical relationship to each other that indicates little modification of the stream from its original condition. Good, fair, and poor are self-explanatory. Consideration has been given to the varying adequacy of sampling different stream systems. Unusual species and habitats, if present, are noted, and sources of problems in the stream, if they can be identified, are indicated.

The order of treatment is roughly north to south. Stream systems are numbered and can easily be located on the accompanying map (Frontispiece). Tributaries of the river cited are discussed only if their condition differs from that of the main stream. Nearby small streams that are not tributaries are sometimes included because of their proximity and similarity. For example, Menominee, Smallpox, and Sinsinawa creeks are not tributaries of the Galena River, but they are close to the Galena River, and it is convenient to treat the four streams as one unit. The Mississippi, Ohio, Wabash, and Illinois rivers are not included in the annotated list, but their species of fishes are included in the counts for the stream systems if records are available for sites near mouths of the streams.

his paper is published by authority of the State of Illinois, Ch. 127, Par. 58.12. It is a contribution from the Section aunistic Surveys and Insect Identification of the Illinois ral History Survey. Dr. Smith is a Taxonomist and Head e Section of Faunistic Surveys and Insect Identification.

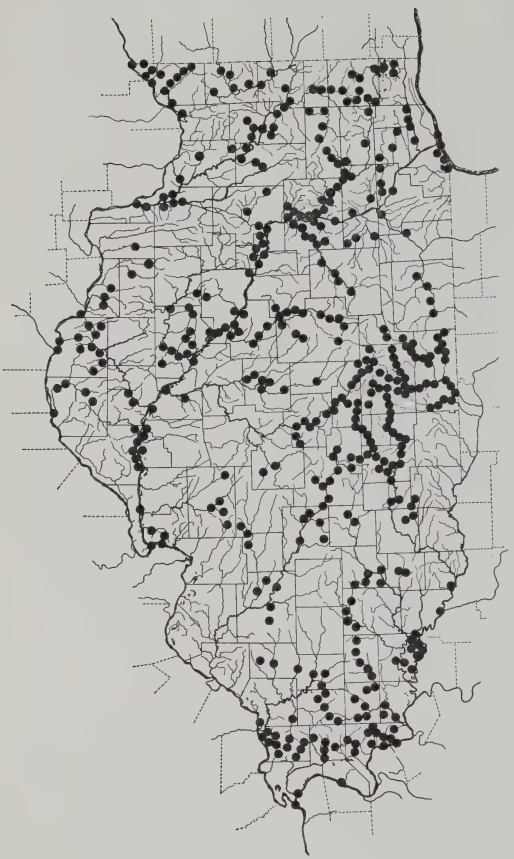

Fig. 1.—Locations of collections of fishes made from 1876 to 1905.

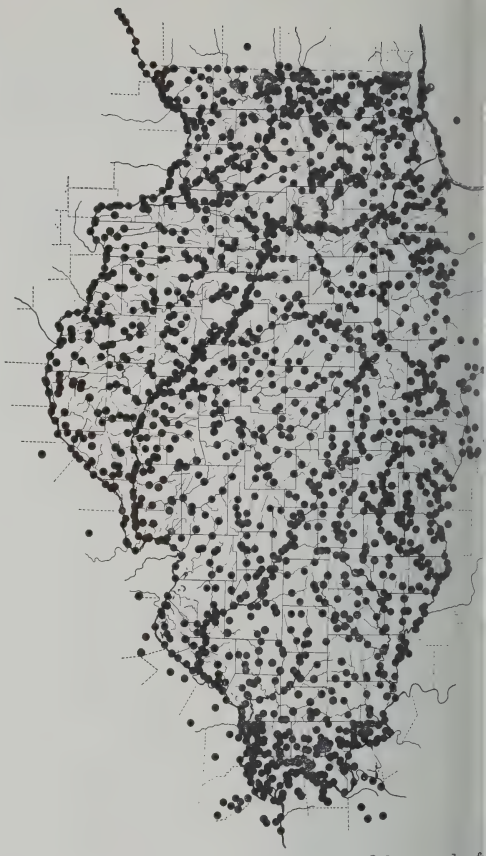

Fig. 2.—Locations of collections of fishes made f 1950 to 1971.

The common names of fishes used in this article are those recommended in American Fisheries Society Special Publication No. 6 (Bailey et al. 1970), in which the scientific names can also be found.

1. *Galena River system* (including Menominee, Sinsinawa, and Smallpox creeks).—Rating good. Species present, 58. Unusual species: longnose dace. Unusual habitats are the gravel-rubble riffles and marginal aquatic vegetation. Barnyard pollution is a minor problem.

2. *Apple River system.*—Rating good to excellent (in upper reaches). Species present, 62. Unusual species: Ozark minnow. Unusual habitats are gravel riffles and clear pools. Some barnyard pollution is present and siltation is a problem in lower reaches, but in general Apple River and its tributaries are exceptionally clean streams.

3. *Plum River system* (including Johnson, Rush, and Otter creeks).—Rating fair. Species present, Unusual species: brassy minnow. Unusual habi are gravel riffles. Barnyard pollution and silta are the principal problems.

4. *Rock-Green River system* (including M dosia Ditch).—Except where it borders or pa through highly urbanized and industrialized ar the Rock River is rated good and, in some areas, cellent. Species present, 98. The Pecatonica Green rivers are only fair because of siltation agricultural pollution. Such tributaries as the K waukee, Leaf, and Kyte rivers and Elkhorn, P Grove, and Piscasaw creeks are good to excell other tributaries are fair to good. Unusual spec lake sturgeon, gravel chub, Ozark minnow, b stickleback, and brassy minnow. Unusual habitats the rocky and gravelly raceways in some of the ri and the small brooks with aquatic vegetation.

pite the dams on the Rock River and the urbanization long its banks, the system has not been affected as everely as many other drainages in the state.

5. *Edwards River system* (including Copperas and ope creeks).—Rating poor to fair. Species present, 2. Habitats are limited, and many of the streams re sand choked and rather sterile. Problems are redging, agricultural pollution, siltation, and the ck of habitat diversity.

6. *Henderson Creek system* (including Ellison nd Honey creeks).—Rating poor to fair. Species resent, 57. Most of the streams contain excessive nounts of silt in their headwaters and sand in lower retches. Problems are siltation, agricultural pollun, and lack of habitat diversity.

7. *Bear Creek system* (including several small, rect tributaries of the Mississippi River).—Rating or to fair. Species present, 54. Sand, gravel, and cky riffles and pools are present, but species dirsity is low. Problems are desiccation during drought riods and rather severe agricultural pollution.

8. *The Sny-Bay Creek system* (including several all, direct tributaries of the Mississippi River).—ting poor to fair. Species present, 76. Many habis are available, and Bay Creek appears to be an tstanding stream with water of high quality. Probns are desiccation during drought periods and agriltural pollution, but these factors cannot account the low species diversity in the system.

9. *The Des Plaines River system* (including Duge River, Salt Creek, and other direct tributaries d canals of the Illinois River).—Rating poor. Species sent, 63. Problems are domestic and industrial lution and extensive modification of streams and bitats. It is remarkable that so many streams still tain fish, although some support only goldfish, dfish-carp hybrids, and green sunfish. Prairie and kson creeks have good species diversity, but Hick- Creek is the outstanding stream in the system l contains populations of such unusual species as northern hogsucker, rosyface shiner, and slender ltom.

10. *Fox River system* (including glacial lakes of e and McHenry counties and Aux Sable Creek).—ing good to excellent. Species present, 102. Unal habitats are the clear well-vegetated natural s, clear gravel-bottomed creeks, and spring-fed ams. Unusual species: blackchin shiner, banded fish, brown bullhead, Iowa darter, banded darter, mottled sculpin. The Fox River proper has some estic and industrial pollution, but most of its itaries have a variety of habitats and rather high ies diversity. Many of the glacial lakes have n ruined by pollution and introduction of sport s; others, such as Channel, Grass, Loon, and ar lakes, contain a rich variety of native species. e of the species in this system do not occur anyre else in the state.

11. *Little Vermilion (of the north) system* (including several nearby direct tributaries of the Illinois River).—Rating fair. Species present, 52. Unusual habitats include clear, gravelly streams. Unusual species: mottled sculpin. The species diversity is rather low, despite the availability of relatively unaltered habitats.

12. *Big Bureau Creek* (including the Illinois and Mississippi Canal and Senachwine Creek).—Rating good to excellent. Species present, 74. Unusual habitats in the area are the fast, sandy and gravelly riffles and clear pools. Some of the streams are sand choked, and the canal is badly silted. Big Bureau Creek and its larger tributaries are relatively unaltered, and agricultural pollution has not had an appreciable effect on the species diversity.

13. *Kankakee-Iroquois River system* (including marginal sloughs and drainage ditches in marshes and sand areas).—Rating excellent. Species present, 72. Unusual habitats are swamps, marshes, clear well-vegetated streams, gravel-rubble riffles, and sand-bottomed pools. Unusual species: ironcolor shiner, weed shiner, blacknose shiner, lake chubsucker, starhead topminnow, northern longear sunfish, and least darter. The Kankakee River and most of its tributaries have excellent species diversity. The Iroquois River is rather sluggish, brushy, and turbid, but some of its tributaries, notably Beaver and Sugar creeks, contain rich assemblages and unusual species.

14. *Mazon Creek system* (including nearby small, direct tributaries of the Illinois River).—Rating good. Species present, 67. Unusual habitats include extensive beds of marginal aquatic vegetation and gravelly riffles and pools. Unusual species: black redhorse, bigeye shiner, and banded darter. Mining and agricultural practices in the area have not appreciably damaged the streams in the system.

15. *Vermilion (of the north) River system* (including Covel Creek and other nearby small, direct tributaries of the Illinois River).—Rating fair. Species present, 80. Unusual habitats are gravelly and sandy riffles and pools, extensive areas of marginal aquatic vegetation, and rocky riffles. Covel Creek has such unusual species as the black redhorse and slender madtom. The Vermilion River has a variety of habitats and should have a richer fish fauna than it has. It has some domestic and agricultural pollution along its length, and its badly silted headwaters are periodically dredged.

16. *Kickapoo Creek* (including Copperas Creek).—Rating good. Species present, 76. Unusual habitats are the clear, gravelly raceways and sand-gravel riffles. Unusual species: blacknose dace, redbelly dace, hornyhead chub.

17. *Spoon River system* (including nearby direct tributaries of the Illinois River).—Rating fair. Species present, 87. In view of the size of the watershed and number of habitats available, the species diversity

should be greater than our collections indicate. Problems are excessive siltation, agricultural pollution, and desiccation of small streams during drought periods.

18. *La Moine River system* (including McKee, Sugar, Crooked, and Bay creeks).—Rating fair. Species present, 78. Problems are siltation, severe agricultural pollution, and desiccation of small streams during drought periods. A few small streams in the area are spring fed and have clear, gravelly riffles.

19. *Mackinaw River system* (including nearby small, direct tributaries of the Illinois River).—Rating good to excellent. Species present, 100. Unusual habitats are sandy and gravelly riffles and pools, and extensive areas with marginal aquatic vegetation. Unusual species: rosyface shiner, silver redhorse, and freckled madtom. Problems are siltation, dredging, and agricultural pollution. Many habitats are present, and species diversity in the Mackinaw River proper is quite high.

20. *Sangamon River system.*—Rating variable. Species present, 94. Unusual habitats are sand-bottomed pools, submerged aquatic vegetation, gravelly riffles, and some deep pools. Unusual species: highfin carpsucker, silver redhorse, ironcolor shiner, spotted sunfish, and banded darter. Problems are siltation; the Lake Decatur dam; industrial, domestic, and agricultural pollution; and dredging. Because of the size of the basin, many different habitats are available and there is a high diversity of species. Salt Creek and its tributaries are less altered than the Sangamon River proper, although both branches have lost some of the species they once had. The headwaters of the Sangamon, Kickapoo Creek, and some small tributaries near the mouth of the Sangamon support particularly rich assemblages of fishes and are rated good; other areas are rated fair.

21. *Indian-Sandy-Apple-Macoupin-Otter creeks* (including other small, direct tributaries of the lower Illinois and Mississippi rivers).—Rating variable. Species present, 87. Unusual habitats include some cold springs and sand-bottomed pools. Unusual species: hornyhead chub, bigeye shiner, redbelly dace, and banded sculpin. Problems are siltation, desiccation during droughts, and agricultural pollution. Otter and Mill creeks have good species diversity; the other streams in the area are rated poor.

22. *Wood River-Cahokia Creek* (including other small tributaries of the Mississippi River in Madison, St. Clair, and Monroe counties).—Rating poor. Species present, 64. Problems are extensive industrial pollution, siltation, and desiccation of small streams during drought periods. The streams in the area lack variety in aquatic habitats and would not have great species diversity even if they were not polluted and otherwise altered.

23. *Kaskaskia-Marys River system.*—Rating variable. Species present, 104. Because of the size of the basin and large variety of habitats, an exceptionally large number of species occurs in this system. Us usual habitats include swamp, sand-gravel riffles an pools, and deep pools. Unusual species: blue sucke freckled madtom, slender madtom, bigeye shine sauger, and river darter. The headwaters of th Kaskaskia are periodically dredged, and the upper se tion receives much agricultural pollution and some i dustrial pollution from a manufacturing plant ne Tuscola. The middle section of the river receiv mine wastes and oil-field pollution. The lower secti has been channelized for barge traffic. Many of th tributaries are low-gradient, brushy sloughs that ha a limited number of habitats. Such tributaries Shoal Creek, Crooked Creek, and Silver Creek a swampy with usually turbid water. Until recen the least disturbed part of the basin was the Kaskask River and its tributaries in Moultrie, Shelby, a Fayette counties, but the recent creation of La Shelbyville destroyed most of the habitats upstre from Shelbyville. Although there is a long list species recorded from the Kaskaskia system, ma species will probably disappear soon. The Ma River would have very poor species diversity w it not for several large-river species that ascend Marys from the Mississippi River.

24. *Big Muddy River system.*—Rating good lower reaches, very poor upstream from Murphysbo Species present, 88. The marginal swamps of lower course are rich in species. Until the recent ation of Lake Kinkaid, Kinkaid Creek was the standing tributary of the Big Muddy. Other tri taries such as Beaucoup Creek, Little Muddy Ri and Crab Orchard Creek are low-gradient, bru streams with little habitat variety, and Crab Orch Lake has destroyed many of the smaller stream the system. Most of the basin suffers from siltat desiccation during drought periods, and oil-field other industrial pollution. The low quality water ports only the most ecologically tolerant and tenac species of fishes in the middle and upper parts of basin.

25. *Clear Creek-Horseshoe Lake system.*—Ra excellent. Species present, 99. Unusual habitats clude the nearly unique Pine Hills swamp, luxu beds of aquatic vegetation, many cold springs, gravelly tributaries, and a large-river habitat near mouth of Clear Creek. Horseshoe Lake is a ty cypress-lined oxbow with good populations of sw species. Unusual species in the system: spring fish, spotted gar, starhead topminnow, banded py sunfish, bantam sunfish, flier, blacktail shiner, ce mudminnow, and river darter. Although muc Clear Creek appears to be a lowland stream, it its clear, gravelly tributaries have an incredible of species, some of which do not occur anywhere in the state.

26. *Cache River system.*—Rating good. Sp present, 81. Although the lower and middle stre

of the Cache River consist of cypress swamp and mud-bottomed sloughs, many of the headwater streams are clear and gravelly, and some are spring fed. Unusual species: flier, blackspotted topminnow, cypress darter, spottail darter, and stripetail darter. Problems are desiccation during drought periods and siltation.

27. *Massac-Bay-Lusk-Big Grand Pierre-Big Creek system* (including many lesser direct tributaries of the Ohio River and some marginal lakes and swamps).—Rating excellent to good. Species present, 79. The outstanding stream in the system is Big Creek, closely followed by Lusk Creek. Unusual habitats are clear, rock-bottomed pools, gravelly riffles, and cold springs. Unusual species: black redhorse, rock bass, smallmouth bass, cypress darter, spottail darter, stripetail darter, and banded sculpin. The smaller streams in the area are rated fair, and those not fed by springs are subject to desiccation during drought periods and to some agricultural pollution. The lowland lakes and swamps have good populations of lacustrine species such as the pugnose minnow.

28. *Saline River system.*—Rating poor. Species present, 57. Problems are stripmine wastes, siltation, oil-field pollution, drainage of natural lakes and ponds, desiccation during drought periods, and a paucity of aquatic habitats. Some parts of the Saline River are devoid of fish because of the discharges of acid from coal mines, and its tributaries have rather low species diversity. Several species have been extirpated.

29. *Little Wabash River system.*—Rating poor in lower reaches but very good in upper part of the system. Species present, 78. Problems are oil-field pollution, siltation, and desiccation during drought periods. Tributaries such as the Skillet Fork, Elm River, and Fox River are low-gradient, brushy streams with oil pollution and very low species diversity. The little Wabash River between Louisville and Neoga has alternating pools and sand or sand-gravel riffles and high species diversity. Unusual species: spotted bass, bigeye shiner, greenside darter, and dusky darter. Tributaries in the upper portion of the basin are shallow, sandy streams with fair species variety; the headwaters of the Little Wabash above Lake Mattoon are badly silted.

30. *Bonpas Creek system* (including some small, direct tributaries of the Wabash River).—Rating fair. Species present, 71. There is a limited number of habitats available in this small watershed, and oil-field pollution, drainage of natural lakes and ponds, and siltation have taken their toll of native species. Unusual species in the system are the pugnose minnow and spotted sucker; the nearby Wabash River has an extremely rich variety of species.

31. *Embarras River system.*—Rating variable. Species present, 92. The lowermost section of the Embarras has oil-field pollution and has been partly channeled, and the headwaters above Lake Charleston are badly silted. A major tributary, the North Fork, has severe oil-field pollution and siltation. These three areas must be rated fair to poor, but the major part of the Embarras River proper and especially the stretch from Charleston to Newton has an excellent variety of habitats and extremely rich species diversity. Unusual species: harlequin darter, dusky darter, eastern sand darter, spotted bass, mountain madtom, and greenside darter. The harlequin darter does not occur anywhere else in the state. The middle section of the Embarras is one of the outstanding Illinois streams.

32. *Direct tributaries of the Wabash River in Crawford, Clark, and Edgar counties.*—Rating good. Species present, 82. The outstanding streams in the system are Mill Creek, Big Creek, and Brouilletts Creek, all of which contain sandy and gravelly pools and riffles and water of high quality. Unusual species: blacknose dace, redbelly dace, greenside darter, and bigeye shiner. Some oil-field pollution exists in the watersheds, but the streams suffer most from desiccation during drought periods.

33. *Little Vermilion-Vermilion River system.*—Rating variable. Species present, 86. The Little Vermilion has been in part rechanneled and dredged and is subject to desiccation during low-water periods. The Vermilion is badly polluted by domestic sewage several miles downstream from Danville but recovers before it leaves the state. The North Fork is badly silted above Lake Vermilion and somewhat polluted below the lake. The West Branch is devoid of fish most of the year because of domestic sewage from Champaign-Urbana, and the East Branch receives some pollution from Rantoul and Chanute Air Force Base. The Salt Fork between Homer and Danville consists of clear pools, wide sand and gravel bars, and rubble-gravel riffles and has quite high species diversity. The outstanding stream in the system, and one of the finest in Illinois, is the Middle Fork, which in addition to the habitats listed for the Salt Fork has some boulder riffles and exposures of bedrock. Unusual species: bluebreast darter, river redhorse, dusky darter, eastern sand darter, mimic shiner, and rosyface shiner. The bluebreast darter does not occur anywhere else in the state.

The number of species in a stream system depends on the number of relatively unmodified habitats available. In general, a large drainage system will contain a greater variety of habitats and more species than a small one. For example, the Kaskaskia River system is the largest in Illinois and has the greatest variety of fishes (104 species). However, the relationship is not absolute. Other stream systems with high species diversity are the Fox (102 species), Mackinaw (100 species), Clear Creek (99 species), Rock-Green (98 species), Sangamon (94 species), and Embarras (92 species). The Fox, Mackinaw, and Embarras systems are moderate in size, and Clear Creek has a rather small drainage basin.

Some of the systems with low species diversity are the Edwards (52 species), Little Vermilion (of the north) (52 species), Plum (53 species), Bear Creek (54 species), and Saline (57 species). Most of these streams have rather small watersheds.

LONG-TERM CHANGES IN ILLINOIS FISH POPULATIONS

If freakish discoveries of aquarium escapees and released pets are ignored, the list of species recorded from Illinois waters stands at 193 (13 naturalized and 180 native species).

Four of the 13 non-native species (brown trout, goldfish, carp, and grass carp) are exotic species. Six of them (rainbow trout, brook trout, coho salmon, chinook salmon, American smelt, and white catfish) are native to other parts of this continent and have been deliberately stocked in Illinois waters. Three of them (sea lamprey, alewife, and threadfin shad) are native to other parts of this country and have recently extended their ranges into Illinois.

Of the 180 native species, 8 (silverjaw minnow, bigmouth shiner, red shiner, redfin shiner, fathead minnow, creek chub, mosquitofish, and redear sunfish) have expanded their ranges in Illinois and increased in abundance. The first three cited thrive in small, shallow streams with sand bottoms and moderate current and are quite resilient to dredging, straightening, and other modifications of streams. It has been shown that in Champaign County, streams tend to be wider and shallower than formerly (Larimore & Smith 1963:320), thus increasing the amount of preferred habitat for these mobile and aggressive species. Similar changes have occurred over the entire state.

The redfin shiner, fathead minnow, and creek chub occupy quiet pools of small streams with silt bottoms, and they are rather tolerant of turbid waters. Siltation and other human alteration of watersheds have increased the amount of favorable habitat for these fishes. The mosquitofish and redear sunfish, native to southern Illinois, have been widely transplanted in efforts to control mosquitoes and to provide another species of panfish in many reservoirs. Both are tolerant of some habitat abuse and have strong dispersal powers.

For 104 of the native species little change was revealed in distribution and abundance. This may be attributed to less adequate sampling during the first censusing as reported by Forbes & Richardson (1908) or because the change in status of these species could not be clearly demonstrated for various reasons.

Eight native species have been extirpated in Illinois and 60 other native species show clear-cut evidence of range shrinkage and decimation. Some of the latter group reveal rather minor reductions in range size and abundance; others are so severel decimated as to be endangered, and some of ther may have been extirpated in Illinois since our surve was completed.

FACTORS RESPONSIBLE FOR CHANGES IN FISH POPULATIONS

If the present ranges and former distributions the native fish species in Illinois are carefully e amined, it is possible in most cases to identify t factor chiefly responsible for the extirpation or decim tion of each species. A tally of the species affect by each identified factor permits an objective asse ment of the environmental changes responsible a brings each factor into perspective.

Silt

Excessive siltation ranks first and is implicated the principal cause for the extirpation of 2 nati species and the decimation of 14 others. Its effe include loss of water clarity and subsequent dis pearance of aquatic vegetation, and the deposit of silt over substrates that were once bedrock, rubb gravel, or sand. Feeding and spawning sites, as w as the usual habitats for such fishes, have been redu over much of the state.

The crystal darter, described from a small tri tary of the Mississippi River in Hancock Cou (Jordan 1878:38), once occurred also in the R River, Little Wabash River, and Mississippi Ri in Jo Daviess County (Forbes & Richardson 1908:3 but it has not been found in the state since 1 The gilt darter was collected in the Rock River early as 1877 (Forbes & Richardson 1908:289) found there in 1927 and 1932 (O'Donnell 1935:4 but it has not been taken anywhere in the state si despite careful searches in recent years.

The bigeye shiner, bigeye chub (Fig. 3), pugnose minnow (Fig. 4), all of which require c water, have been decimated primarily because of disappearance of aquatic vegetation. The moon highfin carpsucker (Fig. 5), rock bass, longear sun and walleye have been adversely affected by incr ing water turbidity. The gravel chub (Fig. 6), O minnow, weed shiner (Fig. 7), western sand da banded darter (Fig. 8), and slenderhead darter reduced ranges because they have lost exte gravel- and sand-substrate habitats to silt.

Excessive siltation has adversely affected f over a long period of time and has drastically alt stream habitats over the entire state with the pos exception of high-gradient streams in extreme n western Illinois.

Drainage

Drainage of natural lakes, sloughs margin large rivers, swamps, and prairie marshes ranks ond in importance and is responsible for the sh

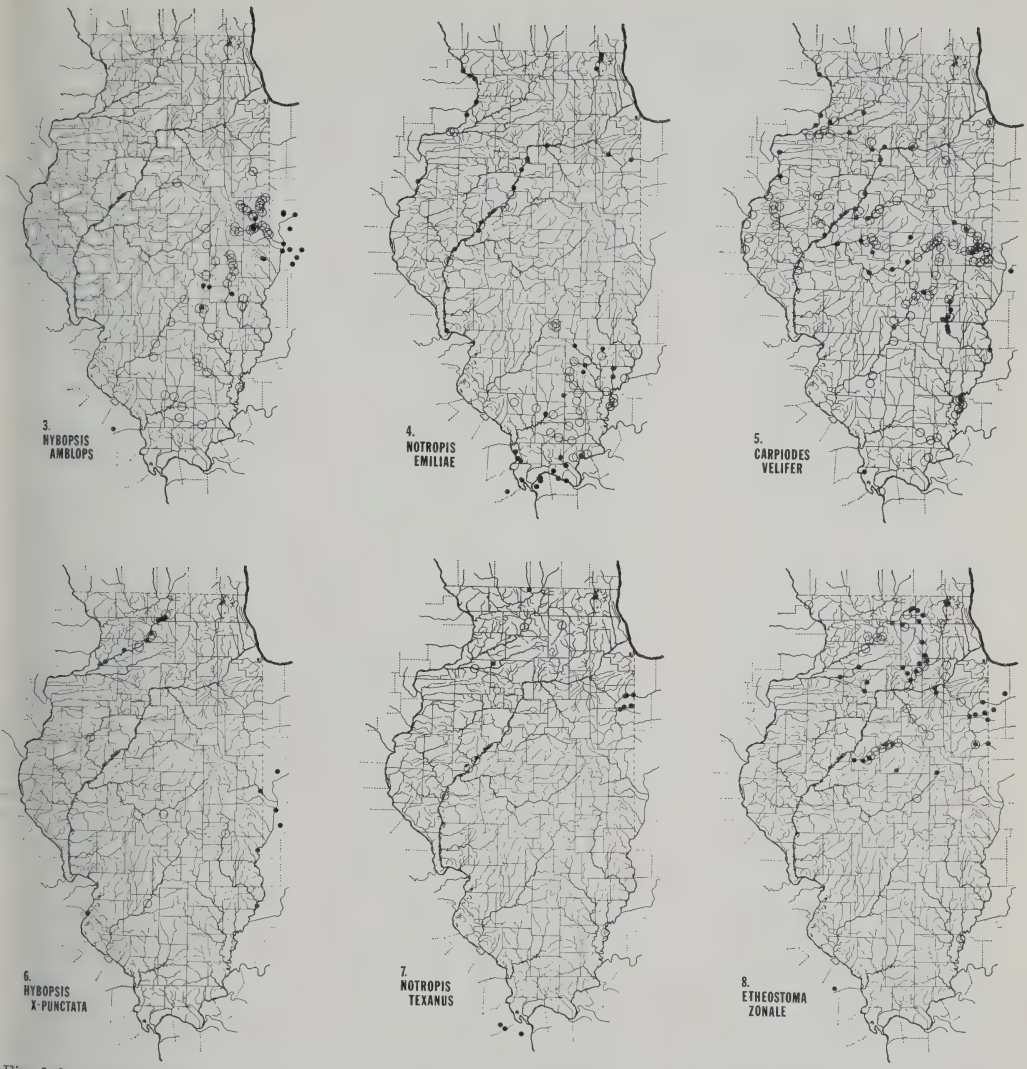

Fig. 3–8.—Some species of fishes decimated because silt has destroyed many of their habitats. The bigeye chub, t collected in Illinois in 1961, may already be extirpated. Circles, before 1905; dots, after 1950.

e in range of 13 native species. The populations of gnose shiner, blackchin shiner, blacknose shiner ig. 9), and banded killifish (Fig. 10) have been luced to a few glacial lakes in extreme northeastern nois as a result of the widespread drainage of ural lakes and marshes in the northern half of the te. The ranges of the bowfin, central mudminnow ig. 11), lake chubsucker, brown bullhead (Fig. 12), rhead topminnow (Fig. 13), pygmy sunfish, bantam sunfish, spotted sunfish, and Iowa darter (Fig. 14) have shrunk as a result of the drainage of the floodplain lakes and sloughs marginal to the large rivers.

Strictly lacustrine species such as the pugnose shiner, blackchin shiner, and banded killifish are especially affected, for when the lake is drained the populations of these fishes are eliminated and there is no opportunity for recruitment into newly created impoundments. Semilacustrine species such as the

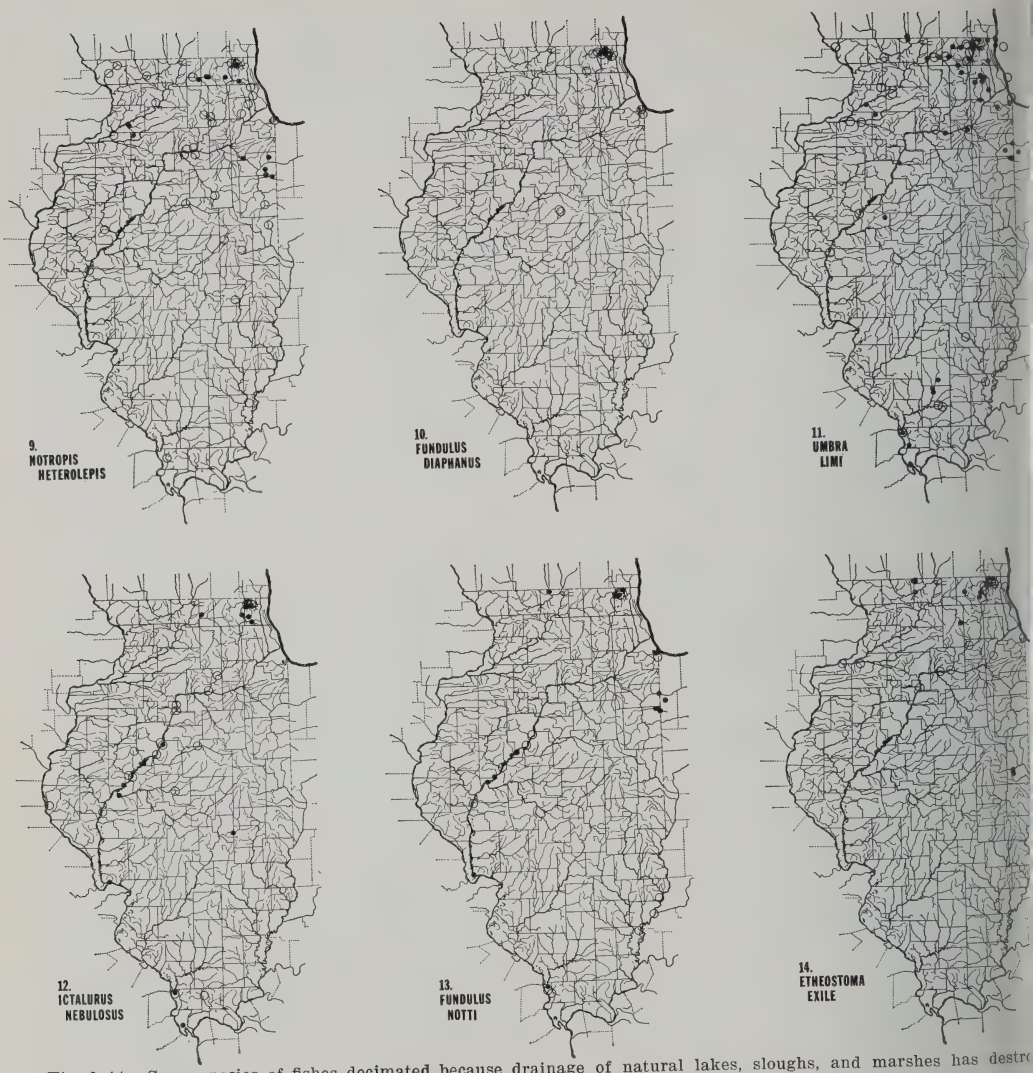

Fig. 9–14.—Some species of fishes decimated because drainage of natural lakes, sloughs, and marshes has destro many of their habitats. Circles, before 1905; dots, after 1950.

bowfin, mudminnow, and others, on the other hand, may have nearby populations in stream oxbows or pools that can disperse into new bodies of water. However, new artificial lakes are usually populated by stocked species and minnow-bucket releases.

Drainage has affected fishes for many years and has produced the most dramatic effects by the elimination of bottomland lakes and sloughs marginal to all of the large rivers and the prairie swales throughout the northern half of Illinois.

Desiccation During Drought

Desiccation of stream systems during drou periods ranks third in importance and is respons for the range shrinkage of 12 species. In re decades the water table has fluctuated more wi than it did before 1930. During severe late sum and fall drought, streams that were once permane flowing now dry up, seeps and springs cease to f and some relatively large rivers temporarily bec medium-sized or small streams.

The effects of desiccation have been particularly devastating on headwater and creek species such as the silvery minnow (Fig. 15), hornyhead chub, striped shiner, redbelly dace, blacknose dace, longnose dace, creek chubsucker (Fig. 16), bluntnose darter (Fig. 17), and slough darter. The effects of reduction in size of streams on large-river species are most dramatically seen in range shrinkage of such typical large-river species as the emerald shiner (Fig. 18), bullhead minnow (Fig. 19), and mud darter (Fig. 20). When large-river habitat is no longer available, these fishes move downstream to their proper habitat or perish. Annual droughts require that tributaries be reoccupied each spring when the streams are flowing again and are of sufficient size to provide the proper habitat.

Stream desiccation is a relatively new factor that has had its most devastating effects since 1930. Prior to that year droughts had less effect because the water table was less variable. Desiccation has been

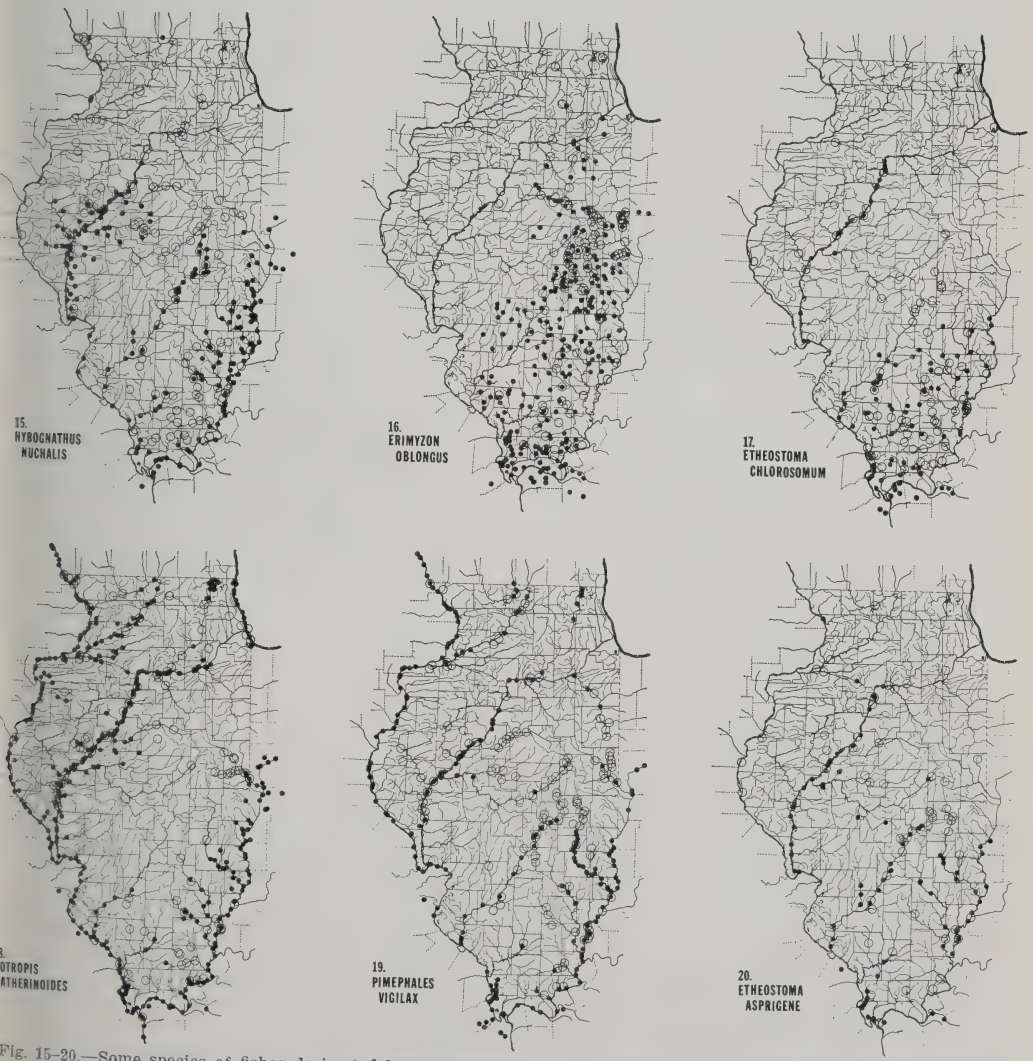

Fig. 15–20.—Some species of fishes decimated because desiccation during drought periods has eliminated many of their bitats. Circles, before 1905; dots, after 1950.

most damaging in southern, western, and central Illinois. During severe droughts, swamps, springs, creeks, and even small rivers have dried up.

Species Interaction

Species interaction following modification of a stream or watershed ranks fourth and is responsible for the extirpation in Illinois of the Ohio lamprey and the rosefin shiner and the decimation of seven other species. Prior to 1917 the Ohio lamprey occurred in the Wabash watershed, but the allied and allopatric chestnut lamprey has since supplanted the Ohio lamprey in all of eastern Illinois and western Indiana (Starrett, Harth, & Smith 1960). The rosefin shiner occurred in extreme southeastern Illinois in the last century but has been supplanted in Illinois and adjacent Kentucky by the more ecologically tolerant and allopatric redfin shiner.

In addition to competition between members of a pair of closely related fishes, there have been interactions unrelated species that resulted in the decimation of several native species. The explosive appearance of the sea lamprey in Lake Michigan in the 1940's was followed by a dramatic decline in populations of the cisco, lake whitefish, round whitefish, lake trout, and burbot. When the ecological balance was upset by sea lamprey predation, the alewife appeared and mushroomed in numbers to become a serious pest in Lake Michigan.

The aggressive and ecologically tolerant red shiner has gradually moved eastward in Illinois (Larimore & Smith 1963) and has displaced the related spotfin shiner (Fig. 21), and steelcolor shiner (Fig. 22) in most parts of central Illinois (Page & Smith 1970). Habitat modification evidently resulted in a breakdown of the reproductive isolating mechanisms in this group of species and permitted the red shiner to hybridize with and eventually replace the other two species.

Such species interactions have been in progress for a long time and throughout the state. The effect on certain native fish by the introduced carp and goldfish are so well known that no comment is required. More recent stockings of the white amur redear sunfish, mosquitofish, white catfish, and salmon species outside their natural ranges may pose equally serious threats to native fish populations in the future

Pollution

Pollution other than silt includes industrial, domestic, and agricultural pollutants and ranks fifth. It can be implicated as the cause for the extirpation of two and decimation of five fishes. The greater redhorse occurred in Salt Creek in northeastern Illinois but disappeared sometime after 1901 when the stream became polluted. The cypress minnow occurred in the Little Muddy River as late as 1940 and was eliminated by pollution, presumably from nearby oil fields.

The ranges of the silver chub, river shiner, brindled madtom (Fig. 23), bluebreast darter, and blackside darter (Fig. 24) are less extensive than formerly because of localized pollution in several stream systems in eastern and southern Illinois.

Virtually all of the streams and lakes in Illinois have been affected to some degree by pollution. Among the most dramatic illustrations are streams and lakes in the greater Chicago area because of industrial and domestic pollution, the Big Muddy and lower Little Wabash systems because of oil-field pollutants, the Illinois River because of domestic sewage from Chicago and other cities, most of the Saline system because of coal mine wastes, sm

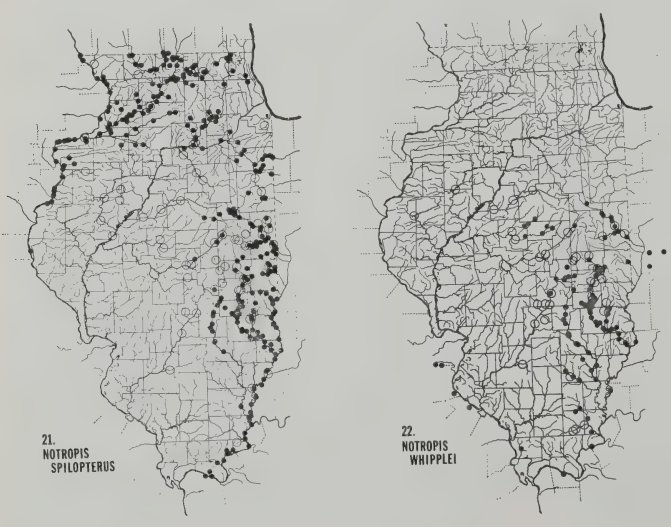

Fig. 21–22.—Two species of fishes d mated because they were unable to c pete with the related red shiner af their original habitats had been alte Circles, before 1905; dots, after 1950.

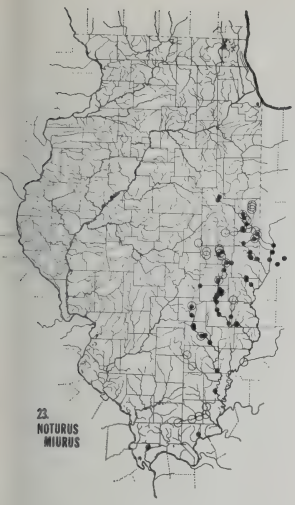

Fig. 23–24.—Two species of fishes decimated because pollution has lowered the water quality of streams that they inhabited. Circles, before 1905; dots, after 1950.

eams in western Illinois because of runoff from hog
ms, and the West Branch of the Salt Fork because
sewage effluents from Champaign-Urbana.

Fish kills have occurred repeatedly when toxicants
h as anhydrous ammonia and cyanide have been
identally or deliberately dumped into streams.
most cases the streams are repopulated in 2 or 3
rs, but endemic and relict species cannot return
e the population has been eliminated.

The revelation that water pollution ranks fifth
ong the principal causes for extirpation and decima-
n of native fishes is rather surprising. However,
ny fishes are remarkably resistant to some degree
pollution as long as the physical habitat remains
ct. Also, in many parts of Illinois, pollution has
ome critically severe only in the last few years,
reas other factors have been operative for a
tury or more.

ns and Impoundments

The construction of dams to create mainstream
oundments ranks sixth and is responsible for the
mation of four species of riffle-inhabiting fishes.
flowing stream consists of alternating riffles and
ls. Riffles may flow over bedrock, boulders, rubble,
el, or sand, and each bottom type comprises a dis-
ive habitat. Pools also may have different habitats,
nding on the type of substrate and current. When
eam is impounded, riffles are eliminated and the
m of the reservoir quickly becomes silt, resulting
nly one habitat. The richness of the fish fauna
rectly related to the number of different habitats
able. Dams also block natural migration and dis-
l of fishes.

he greenside darter (Fig. 25), eastern sand darter
26), fantail darter, and dusky darter have been decimated in the North Fork (Vermilion drainage) and Embarras River by mainstream impoundments (Smith 1968). The bullhead minnow is now restricted to that part of the Embarras River below the Charleston dam but once occurred farther upstream.

The effects of dams on the fishes of the Mississippi, Illinois, Kaskaskia, and Rock rivers are more difficult to document, but the dams are insurmountable to migratory fishes except when the streams are in flood condition, and many miles of stream that formerly contained several distinctive habitats now have only one.

The several proposed reservoirs in Illinois threaten many native species because they are planned for some of the most valuable waterways left, and many of the unique aquatic habitats in the state will be lost if the streams are dammed.

Temperature

The cutting of marginal trees and other vegetation that afford shade, coupled with a reduced flow of cold springs and low water levels during summer droughts, result in higher water temperatures now than formerly. No data on past stream temperatures are available, but temperature offers the most likely explanation for the disappearance of the northern pike in streams of western Union County, where it occurred prior to 1900 (Forbes & Richardson 1908, atlas of maps).

Outlier populations of such species as the hornyhead chub, blacknose dace, longnose dace, redbelly dace, and hogsucker in Union County have also been eliminated, probably because they cannot survive the summer stream temperatures. However, in other areas of the state their decimation is more likely the result of stream desiccation and siltation.

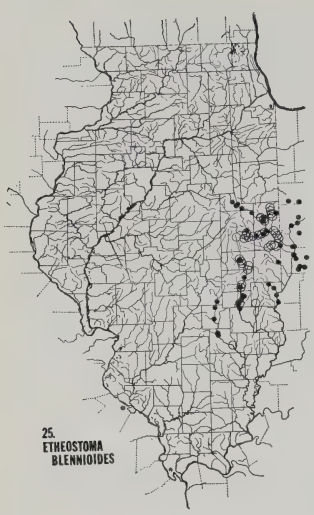

Fig. 25–26.—Two species of fishes decimated because impoundments have destroyed many of their habitats. Circles, before 1905; dots, after 1950.

Unknown Causes

No single factor can be identified as the probable cause for the extirpation in Illinois of the muskellunge, which once occurred in extreme northern Illinois, and the stargazing darter, which once occurred in the lower Wabash River (Smith 1965). The decline of the lake sturgeon, blue sucker, and paddlefish is probably due to a combination of such factors as dams, silt, drainage of marginal lakes, pollution, and overexploitation. The decimation of the orangespotted sunfish, a species rather tolerant of silt and some pollution, is inexplicable.

So-called channel improvement through dredging and stream straightening destroys habitats over extensive stretches of streams, but by itself it cannot be regarded as the principal cause for the decimation of any native fish.

Summary of Factors Discussed

The following tabulation lists the factors primarily responsible for the extirpation of 8, and the decimation of 60, native species of Illinois fishes.

	Number of species extirpated	Number of species decimated
Silt	2	14
Drainage	0	13
Desiccation during drought	0	12
Species interaction	2	7
Pollution	2	5
Dams and impoundments	0	4
Temperature	0	1
Unknown causes	2	4

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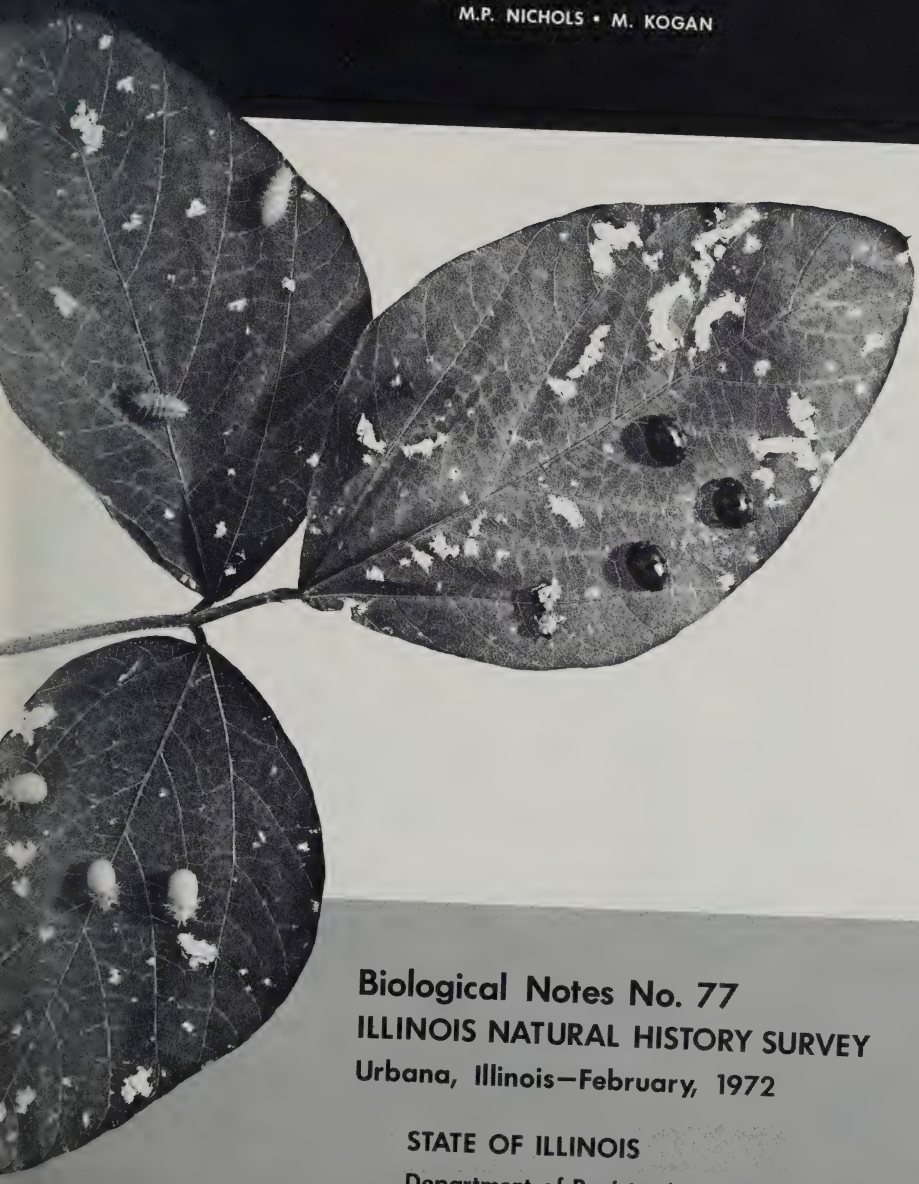
The Literature of Arthropods Associated with Soybeans

I. A BIBLIOGRAPHY OF THE MEXICAN BEAN BEETLE *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae)

M.P. NICHOLS • M. KOGAN



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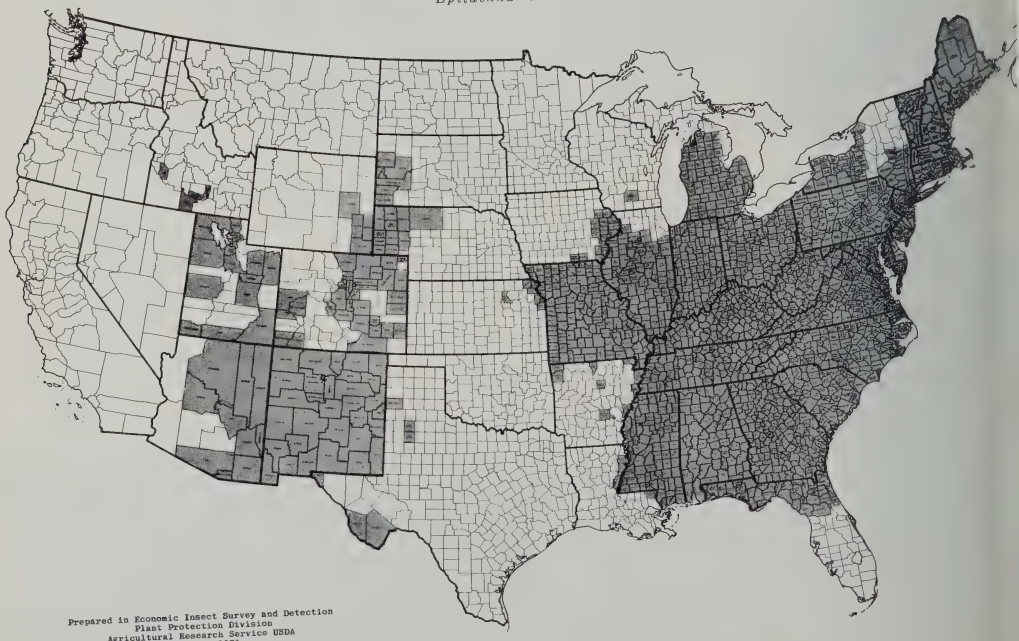
Distribution of Mexican Bean Beetle

Epilachna varivestis



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Plant Protection Division
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The Literature of Arthropods Associated with Soybeans

I. A BIBLIOGRAPHY OF THE MEXICAN BEAN BEETLE, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae)

M. P. Nichols and M. Kogan

The Organization of a Center to search out, store, nd retrieve the literature on insects associated with soyeans is part of a broad program of research and informaon on soybean entomology at the Illinois Natural History urvey and the University of Illinois (Kogan & Luckmann 971)[1].

In establishing this center the main objective was to asemble, for easy and rapid access, the vast mass of data on ybean insects that is scattered throughout the entomologil literature. Furthermore, it was decided to develop this nter as a service-oriented unit to support the Illinois Soyan Entomology Team and its cooperative research and tension personnel. Three parallel activities are under ay: (1) Establish and maintain a collection of scientific ports and extension publications, computerized for rapid trieval; (2) make bibliographic surveys and provide spelized bibliographies to workers in soybean entomology; d (3) compile and publish bibliographies on species or bjects of key importance to soybean entomology.

A bibliography of the Mexican bean beetle—*Epilachna rivestis* Mulsant (Coleoptera: Coccinellidae)—was originlly compiled to provide information on nutrition and host ection of soybean insects in support of ongoing research the Natural History Survey and the University of Illis. The interest in, and economic importance of, this spes in many soybean-producing areas of the United States mpted us to expand the original scope of this literature and present this as the first of a series of bibliographies nsects associated with soybeans.

The Mexican bean beetle is considered in many soybeanducing areas of the United States as one of the most seripests of the crop. Research on chemical control of the le and breeding for plant resistance is being conducted everal institutions. The species is also a convenient labory animal for basic research. Its oligophagous relaship to certain genera of Leguminosae has prompted its in studies of host plant selection. It has become a stanl test animal in pesticide toxicology since its metabolism DDT was studied and reported in a classical work in cology (Sternburg & Kearns 1952)[2].

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This bibliography is not limited to papers dealing with the Mexican bean beetle on soybeans. Many of the listed references do not even mention soybeans. It is intended, however, that the bibliographies in this series be as complete as possible; consequently, they will be of interest beyond the scope of soybean entomology.

The nearly 800 titles in the present list were obtained primarily from standard reference sources and cross references. In addition, a questionnaire was sent to 120 institutions in the United States requesting information on past and current use of the Mexican bean beetle in local research programs. Other references were secured through replies to this questionnaire.

There was little deliberate screening of references for this bibliography in contrast to other entomological bibliographies that have appeared in recent years. Books on general and applied entomology were deleted, as were certain outdated articles of a popular nature on plant damage and insecticidal control. Many short notes and extension type publications, however, were included as they may have some value in tracing the dispersal of the Mexican bean beetle and the evolution of its economic role.

References to the species in brief paragraphs which are parts of annual reports (mostly by agricultural experiment stations) are included as an appendix to the literature and were not tabulated or numbered. The year that appears in this list is that covered by the report and not necessarily the year of publication. It was not intended that this appendix of annual reports be complete, but that it serve primarily as a guide.

In addition, interested researchers are urged to consult the USDA *Cooperative Economic Insect Report,* the USDA *Insect Pest Survey Bulletin,* and the *Canadian Insect Pest Review* for further information concerning the Mexican bean bettle.

The references are numbered and tabulated (see table following the appendix) by subject and periods of publication. Each reference appears only once in the tabulation, under the subject to which it seemed to the authors to make the most significant contribution. However, in the case of those articles which deal with soybeans, the references are listed under the heading SOYBEANS, as well as under one other subject heading. Those interested in more complex areas are advised to peruse also related subjects (e.g. biology and life history, ecology, and distribution). The paucity of references in certain areas led us to combine subjects such as morphology and taxonomy, and physiology and anatomy. The tabulation is offered, therefore, as a simplified subject index to serve as a preliminary key to the literature.

Abbreviations used in the reference entries appear in full in a listing at the end of the paper.

This bibliography is part of Illinois' contribution to the regional USDA project S-74, "Biology and Control of Arthropods on Soybeans."

Mrs. Nancy DeWitt did portions of the search, Mr. Ra Kotek worked in the organization of the files and provide general technical assistance, and O. F. Glissendorf edite the manuscript. Their collaboration is gratefully acknow edged.

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DISTRIBUTION	100,168,332, 472,575,576	102,248	1,2,3,4,5, 28,30,74,84, 93,94,112, 126,127,134, 169,215,223, 224,225,226, 249,251,255, 267,268,307, 342,359,361, 362,370,386, 402,404,409, 423,427,440, 448,479,480, 509,513,537, 538	6,67,87,128, 154,158,179, 221,270,273, 294,316,339, 346,686	10,39,130, 174,204,277, 350,351,514, 517,558,559, 572	104,131			
PHYSIOLOGY & INTERNAL ANATOMY			460	75,227,343, 382	138,276	76,80,579	205,245	542	
TOXICOLOGY			389,390	183,184,213, 286,289,292, 349,395,429, 432,491,518, 556,557,580	20,40,173, 185,186,196, 217,218,219, 222,228,232, 233,240,302, 306,314,324, 325,328,353, 377,378,379, 380,396,412, 428,439,452, 468,476,483, 496,501,502, 503,525,526, 527,528,530, 539,566,567, 568	18,65,90, 139,202,229, 241,242,244, 301,326,327, 329,471,498, 499,510,531	152,197,230, 321,488,519, 560,562	422,489	
HOST SELECTION & FEEDING BEHAVIOR					163,322	175,176,177, 358	25,26,77,78, 98,178,331, 348,415	340	
ECONOMIC ROLE & DAMAGE	201, 247,500,577		32,88,252, 260,263,265, 369,371,385, 441	33,116,118, 120,180,305, 381,522,523	22,159,231, 237,300,354, 383,408,490, 495,515,546, 547	227,438,447	421,458,470	309,368	
BIOLOGICAL CONTROL			14,493	15,97,188, 287,459,497	344		19		
CULTURAL CONTROL				68,69,89, 533	107				
CHEMICAL CONTROL		109,110,431, 511	105,113,114, 157,256,262, 367,384,387, 388,392,484, 485	7,8,13,29, 35,41,45,49, 50,51,52,53, 54,55,62,79, 103,106,111, 119,124,125, 141,147,148, 155,181,182, 187,191,192, 198,212,243, 257,258,274, 275,279,280, 281,288,291, 293,295,299, 303,304,308, 310,347,357, 374,391,394, 424,425,443, 449,487,524, 532,534,535, 550,552,553, 581	9,11,12,34, 36,43,44,47, 56,57,58,59, 60,61,70,71, 72,96,99, 129,133,136, 167,171,172, 209,210,220, 234,236,238, 296,297,355, 364,365,366, 397,398,406, 414,416,430, 442,450,453, 461,465,466, 475,486,492, 494,529,548, 554,563,565, 573,574,583, 585,589	17,21,63, 64,66,73, 108,135,137, 142,164,189, 206,250,298, 311,335,336, 337,373,375, 376,407,410, 418,433,434, 435,467,564, 570,587,588, 590,591	16,82,140, 317,318,319, 419,420,477, 536,569,571	320,551,561	
PLANT RESISTANCE						436	81,211, 584,586	545	

PERIODICAL ABBREVIATIONS

adian Natur. Acadian Naturalist.
r. Chem. Agricultural Chemicals.
r. Leaders Dig. Agricultural Leader's Digest.
. Agr. Exp. Sta. Bull. Alabama Agricultural Experiment Station Bulletin.
. Agr. Exp. Sta. Ext. Serv. Circ. Alabama Agricultural Experiment Station Extension Service Circular.
. Agr. Exp. Sta. Leafl. Alabama Agricultural Experiment Station Leaflet.
er. Agr. American Agriculturalist.
ier. Natur. American Naturalist.
n. Soc. Agr. Lyon. Annales de la Société nationale d'agriculture d'histoire naturelle et des arts utiles de Lyon.
n. Soc. Entomol. Que. Annales de la Société Entomologique du Québec.
. Entomol. Soc. Amer. Annals of the Entomological Society of America.
u. Meet. Entomol. Soc. Japan, Sapporo. Annual Meeting of the Entomological Society of Japan, Sapporo.
u. Rev. Entomol. Annual Review of Entomology.
. Agr. Exp. Sta. Bull. Arizona Agricultural Experiment Station Bulletin.
. Agr. Ext. Serv. Circ. Arizona Agricultural Extension Service Circular.
. Brooklyn Entomol. Soc. Bulletin of the Brooklyn Entomological Society.
. Entomol. Res. Bulletin of Entomogical Research.
. Entomol. Soc. Amer. Bulletin of the Entomological Society of America.
. Natur. Hist. Lab. Univ. Iowa. Bulletin of the Natural History Laboratory, University of Iowa.
N. C. Dep. Agr. Bulletin of the North Carolina Department of Agriculture.
S. Calif. Acad. Sci. Bulletin of the Southern California Academy of Science.
Va. State Crop Pest Comm. Bulletin of the Virginia State Crop Pest Commission.
. Dep. Agr. Bull. California Department of Agriculture Bulletin.
. Dep. Agr. Mon. Bull. California Department of Agriculture Monthly Bulletin.
Entomol. Canadian Entomologist.
egie Inst. Wash. Publ. Carnegie Institute, Washington, Publication.
Agr. Exp. Sta. Bull. Colorado Agricultural Experiment Station Bulletin.
Agr. Ext. Circ. Colorado Agricultural Extension Circular.
Farmers Bull. Colorado Farmer's Bulletin.
. Agr. Exp. Sta. Bull. Connecticut Agricultural Experiment Station Bulletin.
. Agr. Exp. Sta. Circ. Connecticut Agricultural Experiment Station Circular.
. Agr. Exp. Sta. Ext. Serv. Bull. Connecticut Agricultural Experiment Station Extension Service Bulletin.
. Agr. Exp. Sta. Serv. Bull. Connecticut Agricultural Experiment Station Service Bulletin.
State Entomol. Bull. Connecticut State Entomologist's Bulletin.
ib. Boyce Thompson Inst. Contributions from the Boyce Thompson Institute.
ry Gent. Country Gentleman.
Sci. Crop Science.
gr. Exp. Sta. Bull. Delaware Agricultural Experiment Station Bulletin.
Coll. Agr. Ext. Div. Bull. Delaware College of Agriculture Extension Division Bulletin.
Univ. Agr. Exp. Sta. Ext. Serv. Circ. Delaware University Agricultural Experiment Station Extension Service Circular.
Geogr. Economic Geography.
ol. Exp. Appl. Entomologia Experimentalis et Applicata.
ol. News. Entomological News.
ol. Rec. J. Var. Entomological Record and Journal of Variations.
gr. Exp. Sta. Bull. Florida Agricultural Experiment Station Bulletin.
ntomol. Florida Entomologist.
tate Plant Bd. Quart. Bull. Florida State Plant Board Quarterly Bulletin.
lisc. Sec. Agr. Mex. Folleto Miscellaneo, Secretaria de Agricultura Mexico.
Gard. Chron. Amer. Gardener's Chronicle of America.
Ga. Exp. Sta. Bull. Georgia Agricultural Experiment Station Bulletin.
Ga. State Bd. Entomol. Bull. Georgia State Board of Entomology Bulletin.
Ga. Univ. Coop. Ext. Serv. Leafl. Georgia University Cooperative Extension Service Leaflet.
Grain Dealers J. Grain Dealers Journal.
Great Basin Natur. Great Basin Naturalist.
Idaho Agr. Ext. Serv. Bull. Idaho Agricultural Extension Service Bulletin.
Ill. Agr. Exp. Sta. Circ. Illinois Agricultural Experiment Station Circular.
Indiana Agr. Exp. Sta. Circ. Indiana Agricultural Experiment Station Circular.
Int. Congr. Biochem. Symp. International Congress of Biochemistry, Symposium.
Int. Congr. Entomol., Vienna Symp. International Congress of Entomology, Vienna, Symposium.
J. Agr. Food Chem. Journal of Agricultural and Food Chemistry.
J. Agr. Res. Journal of Agricultural Research.
J. Econ. Entomol. Journal of Economic Entomology.
J. Insect Physiol. Journal of Insect Physiology.
J. N. Y. Entomol. Soc. Journal of the New York Entomological Society.
J. Wash. Acad. Sci. Journal of the Washington Academy of Science.
Ky. Agr. Exp. Sta. Circ. Kentucky Agricultural Experiment Station Circular.
Ky. Agr. Exp. Sta. Ext. Circ. Kentucky Agricultural Experiment Station Extension Circular.
La. Agr. Exp. Sta. Bull. Louisiana Agricultural Experiment Station Bulletin.
Maine Agr. Coll. Ext. Serv. Bull. Maine Agricultural College Extension Service Bulletin.
Maine Agr. Exp. Sta. Bull. Maine Agricultural Experiment Station Bulletin.
Maine Agr. Exp. Sta. Misc. Publ. Maine Agricultural Experiment Station Miscellaneous Publication.
Market Growers J. Market Growers Journal.
Md. Agr. Ext. Serv. Circ. Maryland Agricultural Experiment Station Extension Service Circular.
Mass. Agr. Exp. Sta. Bull. Massachusetts Agricultural Experiment Station Bulletin.
Mass. Agr. Exp. Sta. Ext. Serv. Leafl. Massachusetts Agricultural Experiment Station Extension Service Leaflet.
Mass. Agr. Exp. Sta. Ext. Serv. Spec. Circ. Massachusetts Agricultural Experiment Station Extension Service Special Circular.
Mexico, Sec. Fomento, Com. Parasitol. Agr. Circ. Mexico, Secretaria de Fomento Comision de Parasitologia Agricola Circular.
Mich. Agr. Exp. Sta. Circ. Bull. Michigan Agricultural Experiment Station Circular Bulletin.
Mich. Agr. Exp. Sta. Quart. Bull. Michigan Agricultural Experiment Station Quarterly Bulletin.
Mich. Agr. Exp. Sta. Spec. Bull. Michigan Agricultural Experiment Station Special Bulletin.
Mich. State Coll. Agr. Exp. Sta. Ext. Bull. Michigan State College Agricultural Experiment Station Extension Bulletin.
Mich. State Univ. Agr. Exp. Sta. Coop. Ext. Serv. Bull. Michigan State University Agricultural Experiment Station Cooperative Extension Service Bulletin.
Miss. Agr. Coll. Ext. Dep. Bull. Mississippi Agricultural College Extension Department Bulletin.
Miss. Agr. Coll. Ext. Dep. Circ. Mississippi Agricultural College Extension Department Circular.
Miss. Agr. Exp. Sta. Bull. Mississippi Agricultural Experiment Station Bulletin.
Miss. Farm Res. Mississippi Farm Research.
Miss. State Plant Bd. Quart. Bull. Mississippi State Plant Board Quarterly Bulletin.
Mo. Agr. Exp. Sta. Circ. Missouri Agricultural Experiment Station Circular.
Mo. Agr. Ext. Folder. Missouri Agricultural Extension Folder.
Mo. Farmer. Missouri Farmer.
Mo. Univ. Agr. Ext. Serv. Circ. Missouri University Agricultural Extension Service Circular.
Nat. Geogr. Mag. National Geographic Magazine.
Natur. Hist. Natural History.
N. Engl. Homestead. New England Homestead.

N. H. Agr. Exp. Sta. Tech. Bull. New Hampshire Agricultural Experiment Station Technical Bulletin.
N. J. Agr. New Jersey Agriculture.
N. J. Agr. Exp. Sta. Circ. New Jersey Agricultural Experiment Station Circular.
N. J. Agr. Exp. Sta. Ext. Div. Bull. New Jersey Agricultural Experiment Station Extension Division Bulletin.
N. Mex. Agr. Exp. Sta. Bull. New Mexico Agricultural Experiment Station Bulletin.
N. Mex. Agr. Exp. Sta. Ext. Serv. Circ. New Mexico Agricultural Experiment Station Extension Service Circular.
N. Y. Cornell Agr. Exp. Sta. Ext. Bull. New York, Cornell, Agricultural Experiment Station Extension Bulletin.
N. Y. Cornell Agr. Exp. Sta. Mem. New York, Cornell, Agricultural Experiment Station Memoir.
N. Y. Geneva Agr. Exp. Sta. Bull. New York, Geneva, Agricultural Experiment Station Bulletin.
N. Y. Geneva Agr. Exp. Sta. Circ. New York, Geneva, Agricultural Experiment Station Circular.
N. Y. State Agr. Exp. Sta. Farm Res. New York State Agricultural Experiment Station Farm Research.
N. C. Agr. Exp. Sta. Ext. Serv. Circ. North Carolina Agricultural Experiment Station Extension Service Circular.
N. C. Agr. Exp. Sta. Res. Farming. North Carolina Agricultural Experiment Station Research and Farming.
N. C. Agr. Ext. Serv. Folder. North Carolina Agricultural Extension Service Folder.
Ohio Agr. Exp. Sta. Ext. Serv. Bull. Ohio Agricultural Experiment Station Extension Service Bulletin.
Ohio Agr. Exp. Sta. Mon. Bull. Ohio Agricultural Experiment Station Monthly Bulletin.
Ohio Biol. Surv. Bull. Ohio Biological Survey Bulletin.
Ohio J. Sci. Ohio Journal of Science.
Ohio State Univ. Agr. Coll. Ext. Serv. Bull. Ohio State University Agricultural College Extension Service Bulletin.
Pan-Pac. Entomol. Pan-Pacific Entomologist.
Pa. Agr. Exp. Sta. Circ. Pennsylvania Agricultural Experiment Station Circular.
Pa. Agr. Exp. Sta. Ext. Serv. Circ. Pennsylvania Agricultural Experiment Station Extension Service Circular.
Pa. Dep. Agr. Gen. Bull. Pennsylvania Department of Agriculture General Bulletin.
Pa. Dep. Agr. Harrisburg Bull. Pennsylvania Department of Agriculture, Harrisburg, Bulletin.
Proc. Annu. Meet. Conn. Veg. Growers Assoc. Proceedings of the Annual Meeting of the Connecticut Vegetable Growers Association.
Proc. Annu. Meet. Ohio Veg. Growers Assoc. Proceedings of the Annual Meeting of the Ohio Vegetable Growers Association.
Proc. Entomol. Soc. Phila. Proceedings of the Entomological Society of Philadelphia.
Proc. Entomol. Soc. Wash. Proceedings of the Entomological Society of Washington.
Proc. Hawaiian Entomol. Soc. Proceedings of the Hawaiian Entomological Society.
Proc. Indiana Acad. Sci. Proceedings of the Indiana Academy of Science.
Proc. N. Cent. Br. Entomol. Soc. Amer. Proceedings of the North Central Branch of the Entomological Society of America.
Proc. U. S. Nat. Mus. Proceedings of the United States National Museum.
Progr. Farmer. Progressive Farmer.
Purdue Agr. Ext. Dep. Bull. Purdue Agricultural Extension Department Bulletin.
Quart. Bull. State Plant Bd. Miss. Quarterly Bulletin of the State Plant Board of Mississippi.
Rep. Iowa State Hort. Soc. Report of the Iowa State Horticultural Society.
Res. & Farm. Research and Farming.
Roy. Entomol. Soc. London Proc., Ser. C. Proceedings of the Royal Entomological Society of London, Series C.
Rural N. Y. Rural New Yorker.
S. C. Agr. Exp. Sta. Bull. South Carolina Agricultural Experiment Station Bulletin.
S. C. Agr. Exp. Sta. Circ. South Carolina Agricultural Experiment Station Circular.
S. C. Agr. Exp. Sta. Ext. Serv. Bull. South Carolina Agricultural Experiment Station Extension Service Bulletin.
S. C. Agr. Exp. Sta. Ext. Serv. Circ. South Carolina Agricultural Experiment Station Extension Service Circular.
S. Agr. Southern Agriculturalist.
Smithson. Inst. Annu. Rep. Smithsonian Institute Annual Report.
Smithson. Inst. Misc. Coll. Smithsonian Institute Miscellaneous Collection.
S. Planter. Southern Planter.
Soybean Dig. Soybean Digest.
Suppl. Mon. Bull. Calif. State Comm. Hort. Supplement to the Monthly Bulletin of the California State Commission of Horticulture.
Tenn. Agr. Coll. Ext. Serv. Div. Publ. Tennessee Agricultural College Extension Service Division Publication.
Tenn. Agr. Exp. Sta. Bull. Tennessee Agricultural Experiment Station Bulletin.
Tenn. Agr. Exp. Sta. Circ. Tennessee Agricultural Experiment Station Circular.
Tenn. Agr. Ext. Circ. Tennessee Agricultural Extension Circular.
Tenn. State Bd. Entomol. Bull. Tennessee State Board of Entomology Bulletin.
Tenn. Univ. Agr. Ext. Serv. Leafl. Tennessee University Agricultural Extension Service Leaflet.
Trans. Amer. Entomol. Soc. Transactions of the American Entomological Society.
Trans. Peninsula Hort. Soc. Transactions of the Peninsula Horticultural Society, Delaware.
U.S. Dep. Agr., Agr. Res. Adm. Bur. Entomol. Plant Quarantine E. United States Department of Agriculture, Agricultural Research Administration Bureau of Entomology and Plant Quarantine E Series.
U.S. Dep. Agr. Bull. United States Department of Agriculture Bulletin.
U.S. Dep. Agr. Bur. Entomol. Mon. Let. United States Department of Agriculture, Bureau of Entomology, Monthly Letter.
U.S. Dep. Agr. Bur. Entomol. Plant Quarantine News Let. United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, News Letter.
U.S. Dep. Agr. Circ. United States Department of Agriculture Circular.
U.S. Dep. Agr. Div. Entomol. Bull. United States Department of Agriculture, Division of Entomology, Bulletin.
U.S. Dep. Agr. Farmers Bull. United States Department of Agriculture Farmers' Bulletin.
U.S. Dep. Agr. Leafl. United States Department of Agriculture Leaflet.
U.S. Dep. Agr. Misc. Publ. United States Department of Agriculture Miscellaneous Publication.
U.S. Dep. Agr. Tech. Bull. United States Department of Agriculture Technical Bulletin.
U.S. Dep. Agr. Yearb. Agr. United States Department of Agriculture Yearbook of Agriculture.
U.S. Nat. Mus. Bull. United States National Museum Bulletin.
Utah Agr. Ext. Bull. Utah Agricultural Extension Bulletin.
Utah Agr. Ext. Circ. Utah Agricultural Extension Circular.
Vt. Agr. Ext. Serv. Circ. Vermont Agricultural Experiment Station Extension Service Circular.
Va. Agr. Exp. Sta. Bull. Virginia Agricultural Experiment Station Bulletin.
Va. Agr. Ext. Serv. Publ. (Blackburg). Virginia Agricultural Extension Service Publication (Blackburg).
Va. Polytechnic Inst. Ext. Div. News. Virginia Polytechnic Institute Extension Division News.
Va. Truck Exp. Sta. Bull. Virginia Truck Experiment Station Bulletin.
Weekly News Letter. Weekly News Letter, United States Department of Agriculture.
West. Farm Life. Western Farm Life.
W. Va. Agr. Exp. Sta. Bull. West Virginia Agricultural Experiment Station Bulletin.
W. Va. Agr. Ext. Circ. West Virginia Agricultural Extension Circular.
W. Va. Dep. Agr. Circ. West Virginia Department of Agriculture Circular.
World Rev. Pest Control. World Review of Pest Control.
Wyo. Agr. Exp. Sta. Bull. Wyoming Agricultural Experiment Station Bulletin.

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Biol

The Literature of Arthropods Associated with Soybeans

II. A BIBLIOGRAPHY OF THE

SOUTHERN GREEN STINK BUG

Nezara viridula (Linneaus)

(Hemiptera: Pentatomidae)

N. B. DeWitt • G. L. Godfrey

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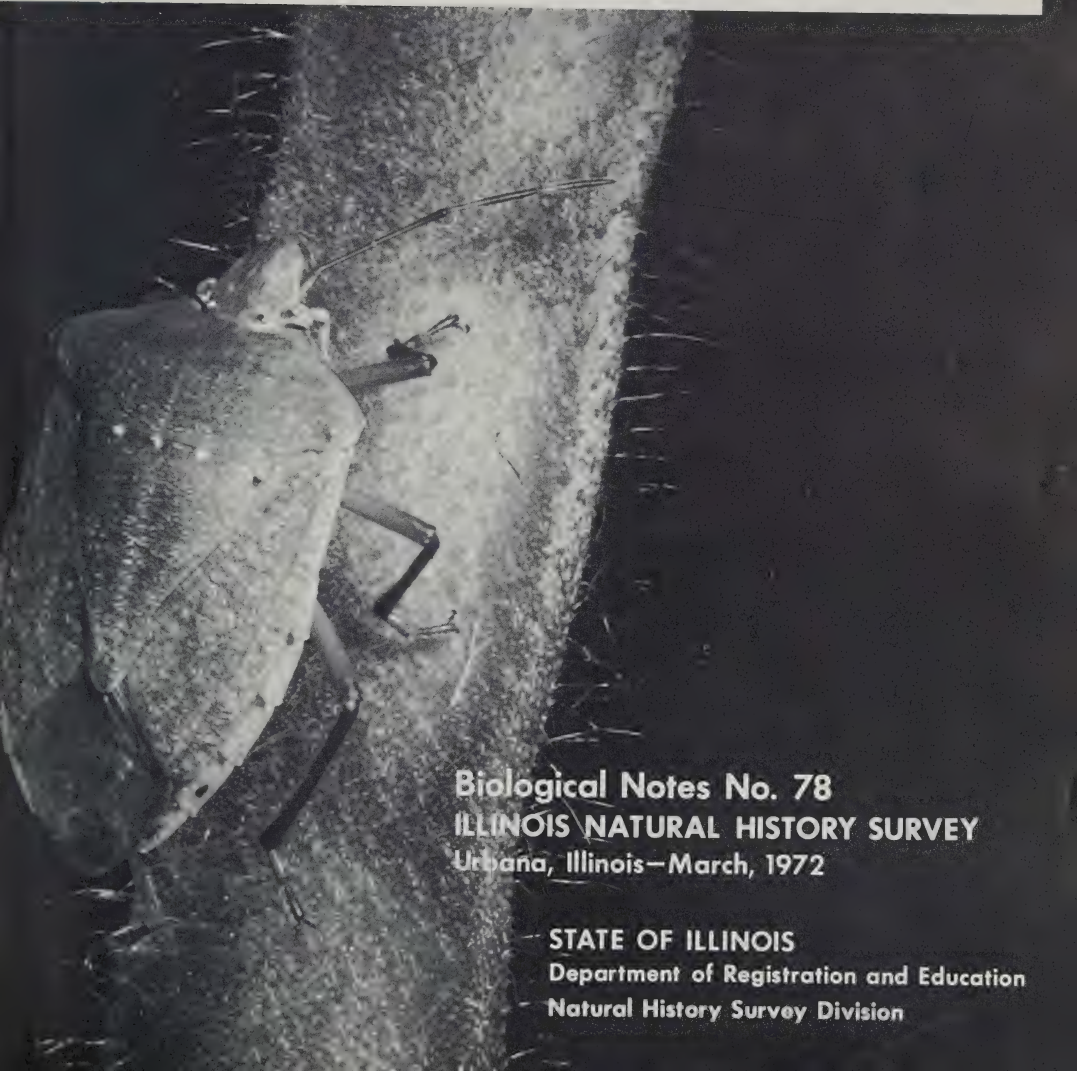

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ILLINOIS NATURAL HISTORY SURVEY
Urbana, Illinois—March, 1972

STATE OF ILLINOIS
Department of Registration and Education
Natural History Survey Division

This paper is a contribution of the Illinois Soybean Entomology Team with support from the Illinois Natural History Survey, the Program for International Research Improvement and Development of the Soybean (PIRIDS), the University of Illinois Departments of Entomology and Horticulture, the Illinois Agricultural Experiment Station, the Rockefeller Foundation, the U.S. Agency for International Development, and the U.S. Department of Agriculture.

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G. P. Waldbauer—Bionomics

Distribution of Southern Green Stink Bug

Nezara viridula

Map courtesy of Commonwealth Agricultural Bureaux

The Literature of Arthropods Associated with Soybeans

II. A BIBLIOGRAPHY OF THE SOUTHERN GREEN STINK BUG, *Nezara viridula* (Linneaus) (Hemiptera: Pentatomidae)

N. B. DeWitt and G. L. Godfrey

This bibliography on *Nezara viridula* (L.) Hemiptera: Pentatomidae) is the second in a series contributing to the knowledge of the biology and control of arthropods on soybeans. In philosophy and scope the literature coverage in this bibliography is similar to that explained by Nichols and Kogan[1] in their publication on the Mexican bean beetle. This bibliography, like the one on the Mexican bean beetle, is not limited to papers dealing with the southern green stink bug on soybeans. Relatively few of the listed references are concerned specifically with soybeans. As for the previous bibliography in this series, the interest of the references will go beyond the scope of soybean entomology.

The titles in the present list were obtained from standard reference sources and cross references. The bibliography is as complete as possible with no deliberate screening. A few of the references have not been specifically searched, due to the inter-library loan service at the University of Illinois being unable to obtain the references in question. These references are designated with an asterisk (*), denoting that the authors have not seen them. A few of these are not fully cited but have been retained.

References to reports in the USDA *Cooperative Economic Insect Report*, USDA *Insect Pest Survey Bulletin*, and *Canadian Insect Pest Review* were not included, for their indexes are very complete. Interested researchers are urged to consult them for information pertaining to southern green stink bug distribution and damage.

The references are numbered and tabulated by subject and periods of publication (see pages 18 and 19), a decade being the smallest period considered. A reference can appear more than once in the subject index. This procedure was used to make the cross referencing for the index as complete as possible.

Abbreviations of periodicals used in this publication appear in full in a listing at the end of the paper.

There are phytophagous species of stink bugs (Pentatomidae) that feed on soybeans in almost every major bean producing region in the world. Based on a cosmopolitan distribution and the degree of feeding damage, one of the most serious species in *N. viridula* (L.), commonly called the southern green stink bug in the United States. The species presumably originated in southern Asia and subsequently spread to the New World. The first New World record for the species is from the West Indies, according to Fabricius (1798), who called it *Cimex spirans*. Other early records are from Jamaica, St. Domingo, and Venezuela (Amyot 1845). Sagra (1857) later recorded it from Cuba. Distant's (1880) localities include Costa Rica and the southern United States, including Texas. The records suggest a somewhat rapid means of dispersal. Wind might be one primary means. Distant (1880) stated that the species was blown on board ship more than 100 miles southwest of Madagascar.

The stink bug feeds on the pods and developing grain, causing pitting of seed, and lowers market value and quality of grain harvests. Its selection of host is not restricted to soybeans or legumes in general. Hoffman (1935) revealed that *N. viridula* is known to feed on three families of monocots and 29 families of diocots with preferences for the Gramineae and Leguminosae, respectively. Perhaps it is this euryphytophagous behavior that has complicated efforts to develop satisfactory control programs for the pest.

The nomenclatorial history of the name *Nezara viridula* (L.) is somewhat exhaustive considering the number of synonyms involved. Those wishing a systematic account of this should consult Freeman's (1940) paper. It should suffice here to say that the frequently encountered names of "smaragdula," "torquata," and "aurantiaca" refer to three distinct color varieties, but have no taxonomic standing.

We are grateful to Mr. K. S. Park for translating several of the articles written in Japanese. Drs. Richard Froeschner and M. Kogan, Miss Martha P. Nichols, and Messrs. J. R. DeWitt and D. W. Webb provided suggestions and assistance during the compilation of the bibliographic entries. Mrs. J. Jansen typed the final copy of the bibliography.

[1] Nichols, M. P., and M. Kogan. 1971. The literature of arthropods associated with soybeans. I. A bibliography of the Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae). Ill. Natur. Hist. Survey Biol. Notes 77.

This paper is published by authority of the State of Illinois, IRS Ch. 1, Par. 58.21. N. B. DeWitt is a Research Assistant at the Illinois Natural History Survey. Dr. G. L. Godfrey is an Assistant Entomologist at the Survey and Assistant Professor at the University of Illinois College of Agriculture.

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SUBJECT \ YEAR	PRIOR TO 1800	1800-1849	1850-1899	1900-1909	1910's	1920's
TAXONOMY	146,147,148,149, 150,183,184,322, 323,504,540	8,9,98,134, 151,175,211,212, 305,414,437,438, 589,617	111,123,155,176, 192,232,303,311, 344,381,433,439, 456,461,469,489, 490,491,492,493, 515,542	124,125,126,233, 235,293,294,341, 524	40,158,420,507, 527,628	49,141,213,4 462
DISTRIBUTION	146,147,148,149, 150,183,322,323, 540	8,151,175,211, 212,305,437,589	111,123,155,176, 231,232,311,433, 456,461,469,489, 490,491,492,493, 514	124,126,235,294, 341,524,525,526	16,17,39,158, 165,245,257,331, 337,494,507,527, 628	49,141,182,2 345,382,385, 611
LIFE HISTORY				341	17,257,331,450, 549	22,131,132,1 241,295,390, 557,597
ECOLOGY					4,253,257	132
GENETICS					599,600	400
MORPHOLOGY & PHYSIOLOGY		134	466		76,257	132,258
ECONOMIC ROLE & DAMAGE			13,238,303	339,341	4,15,16,18,35, 36,37,84,112, 158,165,216,242, 243,245,257,331, 377,409,445,511, 544,545,546,547, 548,549,590,619, 620	5,19,20,21, 120,131,13 182,236,24 252,253,29 302,359,36 382,389,39 398,415,45 462,481,48 512,518,52 531,553,55 561,562,58 585,586,58 596,598,60
HOST SELECTION & FEEDING BEHAVIOR			14,34,238,303, 351,442	126,339,341	17,35,37,77,101, 112,158,165,242, 243,254,256,257, 337,409,420,550	119,120,13 177,182,23 241,295,39 436,460,47 496,512,55 556,557,55 561,582,59 607,609
DISEASE TRANSMISSION					15,406,407,408, 409,511,580,581, 620	120,187,2 475,481,4 521,598,6
TOXICOLOGY						
CHEMICAL CONTROL				339	165,257,543,544	22,131,13 390,460,4 596
BIOLOGICAL-CULTURAL-MECHANICAL CONTROL				308,339	4,17,18,201,242, 243,257,331,544, 545,546,547,549, 550,551,580,619, 620	19,22,119 133,166,1 240,252,2 359,360,3 481,496,5 554,555,5 558,559,5 562,582,5 596,597, 621

1930's	1940's	1950's	1960's	1970's	SOYBEAN
508,532,	162,482,539	52,79,161,204, 239,298,304,459, 517,618	78	629	
3,88. ,356,395, ,626	162,189,313,317, 412,427,539,595	42,79,83,93, 136,146,217,298, 304,309,310,358, 517	75,78,115,199, 270,276,285,291, 366,411,418,446, 624	93,275,428,629	
59,356, ,379,393, ,404,434, ,578,	106,107,143,164, 189,312,380,421, 472,488	52,92,108,170, 181,204,298,397, 517,607	78,97,140,222, 223,260,263,264, 265,266,267,268, 269,270,271,272, 273,276,277,279, 280,282,284,285, 287,288,289,291, 362,367,372,388, 399,446,501	274,275	362,388
55	81,472	52,108,178,204	2,97,115,185, 186,222,223,224, 225,227,228,229, 250,260,263,264, 265,266,267,268, 269,270,273,276, 277,279,280,281, 282,283,284,285, 286,287,288,289, 290,291,367,386, 387,399,411	274,275,591	
		239,335,506	291,624	274,275	
333,334,	28,162	52,197,204,298, 353,419,459,517	50,78,97,156, 157,179,180,185, 186,191,264,282, 285,291,292,352, 446,624	274,275,591	
26,51, 63,64, 130, 52,160, 90,198, 10,215, 59,307, 96,404, 85,502, 33,534, 64,565, 26,627	29,30,45,55, 80,82,102,103, 106,107,127,128, 164,167,171,189, 194,313,315,316, 317,318,319,320, 324,325,326,327, 343,376,380,421, 422,444,454,472, 473,477,480,486, 488,538,541,572, 575,578	38,52,68,83, 89,91,92,108, 121,136,137,144, 145,161,172,181, 193,195,196,251, 261,262,328,354, 413,423,432,435, 443,449,451,487, 517,605,606,615	1,2,78,97,113,115, 140,173, 199,263,276,361, 362,363,366,369, 371,372,388,418, 424,425,457,465, 499,501,510,537, 616	275,330	113,173,262,330, 361,362,363,388, 510
26, 7. 4,71, 30, 0,188, 8,219. 9,347. 4,375. 0,519. 3,626.	28,44,80,82, 86,102,103,106, 107,142,167,189, 317,321,327,380, 421,454,472,473, 480,486,497,538, 572,573,574,594	38,41,42,52, 83,89,91,100, 108,121,136,137, 144,145,181,261, 298,309,349,358, 397,431,435,443, 449,451,487,517, 606,607	3,43,75,78, 97,114,140,199, 269,270,271,278, 279,284,285,291, 361,362,363,366, 399,418,446,447, 465,500,501,537, 616	274,275,330,610	330,361,362,363,
,210, 0,588	214,306,327	42,117,178,262, 348,405,615,625	2,173,499,616	330	173,262,330
			370		
5,485, 0,627	11,30,31,32,55, 65,74,85,95, 103,106,107,128, 129,153,154,169, 203,207,208,209, 247,248,249,327, 343,350,376,412, 421,441,448,473, 477,480,486,509, 576,579,613,614, 622	38,68,121,136, 137,144,145,170, 174,181,193,251, 262,328,336,449, 451,487,605,606, 607,615	1,140,173,272, 362,363,364,366, 370,372,388,411, 424,425,499,501, 513,616		173,362,363,388, 513
961, 72. 159, 255. 9,383. 4,395. 2,403. 5,470. 5,563. 5,567. 5577.	10,29,55,65,66, 67,80,81,90,95, 96,106,107,118, 127,205,206,312, 313,314,315,316, 317,319,320,321, 325,327,380,412, 421,422,426,472, 477,478,479,480, 486,488,503,538, 541,543,572,573, 574,576	42,52,92,108, 109,122,144,145, 170,178,181,328, 397,410,413,423, 431,449,487,607	97,110,112,114, 115,116,140,168, 222,224,226,228, 229,268,269,270, 271,272,276,278, 279,285,290,291, 340,366,368,387, 399,411,418,424, 425,440,446,463, 464,520,601,602, 604	275	

PERIODICAL ABBREVIATIONS

Acta Soc. Sci. Fenn. Acta Societatis Scientearum Fennicae (Helsengforsiae).
Acta Zool. Lilloana. Acta Zoologica Lilloana.
Agr. Gaz. N. S. W. Agricultural Gazette of New South Wales.
Agr. Inform. Agricultural Information.
Agr. J. Egypt. Agricultural Journal of Egypt.
Agr. J. Fiji. Agricultural Journal of Fiji.
Agr. News (Barbados). Agricultural News (Barbados).
Agr. Sci. Rev. Agricultural Science Review.
Agron. Colon. (Paris). L'Agronomie Coloniale (Paris).
Agron. Trop. (Maracay). Agronomia Tropical (Maracay).
Agron. Trop. (Venezuela). L'Agronomie Tropicale (Venezuela).
Ala. Agr. Exp. Sta. Annu. Rep. Alabama Agricultural Experiment Station Annual Report.
Alm. Agr. Bras. (São Paulo). Almanaque Agrícola Brasileiro (Sao Paulo).
Amer. Assoc. Advan. Sci. Publ. Ser. American Association for the Advancement of Sciences Publication Series (Washington, D. C.).
Amer. Nut J. American Nut Journal.
Anim. Behav. Animal Behaviour.
Ann. Hist. Natur. Mus. Nat. Hung. Annales Historico-Naturales Musei Nationalis Hungarici (Budapest).
Ann. Soc. Entomol. Belg. Annales de la Société Entomologique de Belgique.
Ann. Soc. Entomol. Fr. Annales de la Société Entomologique de France.
Ann. Soc. Linn. Lyon (Paris). Annales de la Société Linnéenne de Lyon (Paris).
Ann. Fac. Agr. Univ. Pisa, New Ser. Annali della Facolta di Agraria. University di Pisa. New Series.
Ann. Entomol. Soc. Amer. Annals of the Entomological Society of America.
Ann. Mag. Natur. Hist. Annals and Magazine of Natural History.
Ann. S. Afr. Mus. Annals of the South African Museum.
Ann. Univ. Stellenbosch. Annals of the University of Stellenbosch.
Annu. Bull. Agr. Dep. Nigeria. Annual Bulletin of the Agricultural Department, Nigeria.
Annu. Rep. Commonw. Sci. Ind. Res. Org. (Australia). Annual Report of the Commonwealth Scientific and Industrial Research Organization (Australia).
Annu. Rep. Coun. Sci. Ind. Res. (Australia). Annual Report of the Council for Scientific and Industrial Research (Australia).
Antigua Rep. Agr. Dep. Antigua Report of the Agricultural Department (Barbados).
Appl. Entomol. Zool. Applied Entomology and Zoology.
Araneta J. Agr. Araneta Journal of Agriculture.
Arch. Biochem. Biophys. Archives of Biochemistry and Biophysics.
Arch. Zool. Ital. (Torino). Archivio Zoologico Italiana (Torino).
Argentina Minist. Agr. Circ. Argentina Ministerio de Agricultura Circular.
Arkansas Agr. Exp. Sta. Bull. Arkansas Agricultural Experiment Station Bulletin.
Arkansas Farm Res. Arkansas Farm Research.
Asoc. Latinoamer. Entomol. Publ. (Bogotá). Asociacion Latinoamericana de Entomologia Publicacion (Bogotá).
Aust. J. Biol. Sci. Australian Journal of Biological Science.
Aust. J. Zool. Australian Journal of Zoology.
Aust. Zool. Australian Zoologist.
Barbados Dep. Agr. Rep. Barbados Department of Agriculture Report.
Biol. Vestn. (Ljubljana). Biološki Vestnik (Ljubljana).
Bol. Tec. Inst. Agron. Est. São Paulo. Boletim Técnico Instituto Agronômico do Estado de São Paulo (Campinas).
Bol. Tec. Inst. Agron. Sul. Boletim Tecnico do Instituto Agronômico do Sul.
Bol. Patol. Veg. Entomol. Agr. Boletín de Patología Vegetal y Entomología Agrícola (Madrid).
Bol. Soc. Entomol. Espan. Boletin de la Sociedad Entomologia de Espana.
Boll. Entomol. Agr. Patol. Veg. (Padova, Gennaio). Bollettino di Entomologia Agraria Patologia Vegetale (Padova, Gennaio).
Boll. Lab. Zool. Generale Agr. (Portici). Bollettino de Laboratorio di Zoologia Generale e Agraria (Portici).
Boll. Soc. Entomol. Ital. (Genova). Bollettino della Societa Entomologia Italiana (Genova).
Bragantia. Bragantia. Boletim Técnico do Instituto Agronômico do Estado de São Paulo.
Bull. Agr. Congo Belge. Bulletin Agricole du Congo Belge (Brussells).
Bull. Amer. Mus. Natur. Hist. Bulletin of the American Museum of Natural History.
Bull. Buffalo Soc. Natur. Sci. Bulletin of the Buffalo Society of Natural Sciences.
Bull. Entomol. Res. Bulletin of Entomological Research.
Bull. Kochi Inst. Agr. Forest Sci. Bulletin of the Kochi Institute of Agriculture and Forest Science.
Bull. Miyazaki Coll. Agr. Forest. (Miyazaki). Bulletin of the Miyazaki College of Agriculture and Forestry (Miyazaki).
Bull. Nat. Inst. Agr. Sci. Ser. C. (Plant Pathol. Entomol.) (Tokyo). Bulletin of the National Institute of Agricultural Sciences. Series C. (Plant Pathology and Entomology) (Tokyo).
Bull. Soc. Fouad I. Entomol. Bulletin de la Société Fouad I^er d'Entomologie.
Bull. Soc. Roy. Entomol. Égypte. Bulletin de la Société Royale Entomologique de l'Égypte.
Bull. Torrey Bot. Club. Bulletin of the Torrey Botanical Club.
Burma Entomol. Dep. Rep. Entomol. Burma Entomology Department Report of the Entomologist.
Calif. Bur. Entomol. Plant Quar. Memo. California Bureau of Entomology and Plant Quarantine Memo.
Can. Entomol. Canadian Entomologist.
Cawnpore Agr. Sta. Rep. (Allahabad). Cawnpore Agricultural Station Report (Allahabad).
Ceylon Dep. Agr. Adm. Rep. Ceylon Department of Agriculture Administration Report.
Ceylon J. Sci. Biol. Sci. Ceylon Journal of Science. Biological Science.
Citrus Ind. Citrus Industry.
Citrus Mag. Citrus Magazine.
Coimbatore Adm. Rep. Govt. Entomol. Coimbatore Administration Report of the Government Entomologist.
Colon. Off. Rep., Misc. Ser. (London). Colonial Office Reports. Miscellaneous Series. Colonial Office (London).
C. R. Séances Acad. Sci. (Paris). Comptes Rendus des Séances de L'Académie de Sciences (Paris).
Coop. Econ. Insect Rep. Cooperative Economic Insect Report.
Denkschr. Med. Naturw. Ges. Jena. Denkschriften der Medicinisch Naturwissenschaftlichen Gesellschaft zu Jena (Jena).
Dep. Agr. Straits Settlements and Federated Malay States Sci Ser. Department of Agriculture Straits Settlements and Federated Malay States. Science Series.
Egypt Minist. Agr. Tech. Sci. Serv. Bull. Egypt Ministry of Agricultur Technical and Scientific Service Bulletin.
Empire Cotton Grow. Corp. Progr. Rep. Exp. Sta. Empire Cotto Growing Corporation Progress Reports from Experiment Stations.
Empire Cotton Grow. Rev. Empire Cotton Growing Review.
Empire Mktg. Bd. Bull. Empire Marketing Board Publications.
Entomol. Amer. Entomologica Americana.
Entomol. Mem. Agr. Dep. India. Entomological Memiors of the Agr cultural Department, India.
Entomol. News. Entomological News.
Entomol. Soc. Queensland Minut. Meet. Entomological Society Queensland Minutes of Meeting.
Entomol. Mon. Mag. Entomologists' Monthly Magazine.

ra-Rep. Agr. Exp. Sta. Formosa (Taihoku). Extra-Report of the Agricultural Experiment Station of Formosa (Taihoku).
ts Sug. Facts about Sugar.
. Agron. Montevideo Bol. Facultad de Agronomia de Montevideo oletin.
ming S. Afr. Farming in South Africa.
. Malay States Dep. Agr. Annu. Rep. Federated Malay States Department of Agriculture Annual Report.
d Mus. Natur. Hist. Publ. Zool. Ser. Field Museum of Natural History. Zoological Series.
Agr. Exp. Sta. Annu. Rep. Florida Agricultural Experiment Station Annual Report.
Agr. Exp. Sta. Bull. Florida Agricultural Experiment Station Bulletin.
Agr. Exp. Sta. Circ. Florida Agricultural Experiment Station Circular.
Agr. Exp. Sta. Ext. Serv. Bull. Florida Agricultural Experiment Station Extension Service Bulletin.
Agr. Exp. Sta. Press Bull. Florida Agricultural Experiment Station ess Bulletin.
Bugg. Florida Buggist.
Entomol. Florida Entomologist.
Grower. Florida Grower.
State Plant Bd. Quart. Bull. Florida State Plant Board Quarterly lletin.
osan Govt. Agr. Exp. Sta. Publ. Formosan Government Agricultural Experiment Station Publication.
Agr. Exp. Sta. Bull. Georgia Agricultural Experiment Station Bulletin.
Coastal Plain Exp. Sta. Bull. Georgia Coastal Plain Experiment tion Bulletin.
tate Bd. Entomol. Bull. Georgia State Board of Entomology Bulle-
da Rep. Agr. Dep. Grenada Report of the Agricultural Department (Trinidad).
Gst. Citrus Exch. Educ. Bull. Gulf Coast Citrus Exchange Educational Bulletin.
ii Farm Sci. Hawaii Farm Science.
ii Sugar Plant. Assoc. Exp. Sta. Rep. Hawaii Sugar Planters Association Experiment Station Report.
ii. Plant. Rec. Hawaiian Planters Record.
gia (Zool.). Iheringia (Zoologia).
Mus. Notes. Indian Museum Notes.
. Fitopatol. (Bologna). Informatore Fitopatologico (Bologna).
Pest Surv. Bull. Insect Pest Survey Bulletin.
. Kongr. Entomol. Vien. Eleventh Internationaler Kongress für omologie Vien.
ep. Agr. Adm. Rep. Iraq Department of Agriculture Administration Report.
gr. L'Italia Agricola (Piecenza).
a Dep. Agr. Annu. Rep. (Kingston). Jamaica Department of culture Annual Report (Kingston).
ca Gaz. Suppl. (Kingston). Jamaica Gazette Supplement gston).
Appl. Entomol. Zool. Japanese Journal of Applied Entomology Zoology.
Ecol. Japanese Journal of Ecology.
. Soc. Bengal. Journal of the Association Society of Bengal.
Inst. Agr. Sci. Journal of the Australian Institute of Agriculturence.
bay Natur. Hist. Soc. Journal of the Bombay Natural History ty.
. Sci. Ind. Res. (Australia). Journal of Council for Scientific ndustrial Research (Australia).
Agr. S. Aust. Journal of the Department of Agriculture of South alia.
Agr. West. Aust. Journal of the Department of Agriculture of ern Australia.
J. Econ. Entomol. Journal of Economic Entomology.
J. Fed. Malay States Mus. Journal of the Federated Malay States Museums (Kuala Lumpur).
J. Ga. Entomol. Soc. Journal of the Georgia Entomological Society.
J. Insect Physiol. Journal of Insect Physiology.
J. Microsc. (Paris). Journal de Microscopie (Paris).
J. Morphol. Journal of Morphology.
J. Mysore Agr. Exp. Union (Bangalore). Journal of the Mysore Agricultural and Experimental Union (Bangalore).
Kansai Byochungai Kenkyukai-Ho. Kansai Byochungai Kenkyukai-Ho (Proceedings of the Kansai Plant Protection).
Kans. State Bd. Agr. Rep. Kansas State Board of Agriculture Report.
Lab. Entomol. Agr. "Filippo Silvestri" (Portici). Laboratorio di Entomologia Agraria "Filippo Silvestri" (Portici).
Lingnan Sci. J. Lingnan Science Journal.
Madagascar Bull. Agr. Madagascar Bulletin Agricole.
Madras Agr. J. Madras Agricultural Journal.
Meded. Alg. Proefsta. AVROS Medan Alg. Serie (Batavia). Mededeelingen van het Algemeen Proefstation der AVROS Medan Algemeen Serie (Batavia).
Meded. Alg. Proefsta. Landb. (Buitenzorg). Mededeelingen van het Algemeen Proefstation voor Landbouw (Buitenzorg).
Meded. Deli-Proefsta. Medan. Mededeelingen van het Deli-Proefstation te Medan (Sumatra).
Meded. Inst. Plziekt. (Buitenzorg). Mededeelingen van het Instituut voor Plantenziekten (Buitenzorg).
Meded. Proefsta. Vorstenl. Tabak Klaten. Mededeelingen van het Proefstation voor Vorstenlandsche Tabak, Klaten (Buitenzorg).
Meded. Uit's Lands Plant. Mededeelingen Uit's Lands Plantentium.
Mel. Entomol. Meletemata Entomologia (Petropoli).
Mém. Acad. Roy. Sci. Inst. Fr. Mémoires de l'Academie Royale des Sciences Institut de France.
Mém. Inst. Sci. Madagascar, Sér. E, Entomol. Mémoires d L'Institut Scientifique de Madagascar. Série E, Entomologie.
Mem. Soc. Sci. Natur. Maroc. Mémoires de la Société des Sciences Naturelles du Maroc.
Mem. Dep. Agr. India Entomol. Ser. Memoirs of the Department of Agriculture in India. Entomological Series.
Mem. Estac. Exp. Agr. la Molina (Lima). Memoria Estacion Experimental Agricola de la Molina (Lima).
Mem. Estud. Mus. Zool. Univ. Coimbra. Memórias e Estudo do Museu Zoológico da Universidade de Coimbra.
Miss. Agr. Exp. Sta. Rep. Mississippi Agricultural Experiment Station Report.
Monogr. Angew. Entomol. (Berlin). Monographien zur Angewandten Entomologie (Berlin).
Mushi (Suppl.) Mushi (Supplement).
Naples Univ. Lab. Entomol. Agr. Boll. Naples Universita Laboratorio di Entomologia Agraria Bollettino.
New Guinea Agr. Gaz. New Guinea Agricultural Gazette.
N. S. W. Dep. Agr. New South Wales Department of Agriculture.
N. S. W. Govt. Gaz. New South Wales Government Gazette.
N. Y. Cornell Agr. Exp. Sta. Ext. Bull. New York, Cornell, Agricultural Experiment Station Extension Bulletin.
N. Z. Dep. Agr. J. New Zealand Department of Agriculture Journal.
N. Z. Entomol. Res. Sta. Publ. New Zealand Entomological Research Station Publication.
N. Z. Gard. New Zealand Gardner.
N. Z. J. Agr. New Zealand Journal of Agriculture.
N. Z. J. Sci. New Zealand Journal of Science.
N. Z. J. Sci. Tech., Sec. B. New Zealand Journal of Science and Technology, Section B.
Newell Entomol. Soc. J. Newell Entomological Society Journal.
N. C. Agr. Exp. Sta. Bull. North Carolina Agricultural Experiment Station Bulletin.
Noumea Inst. Fr. Océanie. Noumea Institut de Francais d'Océanie.
Nyasaland Prot. Dep. Agr. Annu. Rep. Nyasaland Protectorate Department of Agriculture Annual Report (Zomba).

Off. Coun. Agr. Forest. Aquat. Technol. Office of Council Agricultural, Forestry, and Aquatic Technology.

Öfvers. K. Svenska VetenskAkad. Förh. (Stockholm). Ofversigt af Kongliga Svenska Vetenskaps-Akademiens Förhandlingar (Stockholm).

Ohio Agr. Exp. Sta. Mon. Bull. Ohio Agricultural Experiment Station Monthly Bulletin.

Orchardist N. Z. Orchardist of New Zealand.

Pac. Insects. Pacific Insects.

Philippine Agr. Rev. Philippine Agricultural Review.

Philippine Entomol. Philippine Entomologist.

Physis. Physis. Revista de la Sociedad Argentina de Ciencias Naturales.

Plant Dis. Rep. Plant Disease Reporter.

P. R. Univ. J. Agr. Porto Rico University Journal of Agriculture.

Proc. Calif. Acad. Sci. Proceedings of the California Academy of Science.

Proc. Entomol. Soc. Wash. Proceedings of the Entomological Society of Washington.

Proc. Fla. State Hort. Soc. Proceedings of the Florida State Horticultural Society.

Proc. Hawaii. Entomol. Soc. Proceedings of the Hawaiian Entomological Society.

Proc. 7th Int. Congr. Entomol. Madrid. Proceedings of the Seventh International Congress of Entomology, Madrid.

Proc. 12th Int. Congr. Entomol. London. Proceedings of the Twelfth International Congress of Entomology, London.

Proc. Linnean Soc. N. S. W. Proceedings of the Linnean Society of New South Wales.

Proc. 6th Pac. Sci. Congr. Pac. Sci. Assoc. Proceedings of the Sixth Pacific Science Congress of the Pacific Science Association.

Proc. Roy. Soc. London Ser. B. Biol. Sci. Proceedings of the Royal Society of London. Series B. Biological Science.

Proc. Soil Crop Sci. Soc. Annu. Meet. Proceedings of the Soil and Crop Science Society of Florida Annual Meeting.

Proc. Tex. Pecan Growers Assoc. Proceedings of the Texas Pecan Growers Association.

Proc. U. S. Nat. Mus. Proceedings of the United States National Museum.

Proc. Zool. Soc. Bengal (Calcutta). Proceedings of the Zoological Society of Bengal (Calcutta).

Proc. Zool. Soc. London. Proceedings of the Zoological Society of London.

Punjab Rep. Dep. Agr. Punjab Report of the Department of Agriculture.

Queensland Agr. J. Queensland Agricultural Journal.

Queensland Dep. Agr. Stk. Annu. Rep. Queensland Department of Agriculture and Stock Annual Report.

Queensland J. Agr. Anim. Sci. Queensland Journal of Agricultural and Animal Science.

Rec. 7th Symp. Jap. Appl. Anim. Entomol. Soc. Record of the Seventh Symposium of the Japanese Applied Animal and Entomological Society.

Rep. Dir. Agr. Tonga (Nuku'alofa). Report of the Director of Agriculture, Tonga (Nuku'alofa).

Rep. Proc. 5th Entomol. Meet., Pusa. Report of the Proceedings of the Fifth Entomological Meetings, Pusa.

Republica Argentina Minist. Agr. Sección Propaganda e Informes Circ. (Buenos Aires). Republica Argentina Ministerio de Agricultura, Sección Propaganda e Informes Circular (Buenos Aires).

Res. Pop. Ecol. Researches in Population Ecology.

Rev. Agr. (Piracicaba). Revista de Agricultura (Piracicaba).

Rev. Agr. Comerc. Trabajo (Cuba). Revista de Agricultura Comercio y Trabajo (Cuba).

Rev. Agron. (Pôrto Alegre). Revista Agronômica (Pôrto Alegre).

Rev. Soc. Entomol. Argentina. Revista de la Sociedad Entomologica Argentina.

Rev. Entomol. (Strassburg). Revue Entomologique (Strassburg).

Santiago de las Vegas, Cuba Estac. Exp. Agron. Santiago de las Vegas, Cuba. Estación Experimental Agronómica.

Santiago de las Vegas, Cuba Estac. Exp. Agron. Bol. Tec. Santiago de las Vegas, Cuba. Estación Experimental Agronómica Boletin Tecnico.

Santiago de las Vegas, Cuba Estac. Exp. Agron. Circ. Santiago de la Vegas, Cuba. Estación Experimental Agronómica Circular.

Secr. Est. Negocios Agr. Ind. Comerc. Seccao Inform. Propagand. Agr. Secretaria de Estado dos Negocios de Agricultura, Industria Comercio Seccao de Informacoes e Propaganda Agricola.

Serv. Inform. Agr. Minist. Agr. (Rio de Janeiro). Serviço de Informaçã Agrícola Ministério de Agricultura (Rio de Janeiro).

S. C. Ext. Serv. Circ. South Carolina Extension Service Circular.

Soybean Dig. Soybean Digest.

St. Vincent Rep. Agr. Dep. St. Vincent Report of the Agricultural Department.

Sultanic Agr. Soc. Cairo, Tech. Sect. Bull. Sultanic Agricultural Society of Cairo, Technical Section Bulletin.

Sunshine State Agr. Res. Rep. Sunshine State Agricultural Research Report.

Tasmanian J. Agr. Tasmanian Journal of Agriculture.

Termész. Füzet. Természetrajzi Füzetek: Kiadja a Magyar Remeze Museum.

Terre Maroc. La Terre Marocaine.

Tex. Dep. Agr. Bull. Texas Department of Agriculture Bulletin.

Tex. Exp. Sta. Annu. Rep. Texas Experiment Station Annual Report

Tortula Rep. Agr. Dep. Tortula Report of the Agricultural Department.

Trans. Amer. Entomol. Soc. Transactions of the American Entomological Society.

Trans. 4th Int. Congr. Entomol. Ithaca. Transactions of the Fourth International Congress of Entomology, Ithaca.

Trans. N. Z. Inst. Transactions of the New Zealand Institute.

Trans. Proc. N. Z. Inst. Transactions and Proceedings of the New Zealand Institute.

Trans. Roy. Entomol. Soc. London. Transactions of the Royal Entomological Society of London.

Trans. Roy. Soc. N. Z. Transactions of the Royal Society of New Zealand (Wellington).

Trop. Agr. (Trinidad). Tropical Agriculture (Trinidad).

Trop. Agr. (Peradeniya). Tropical Agriculturist (Peradeniya).

Uganda Dep. Agr. Annu. Rep. Uganda Department of Agricult Annual Report.

U.S. Dep. Agr., Agr. Res. Adm. Bur. Entomol. Plant Quar. Un States Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine.

U.S. Dep. Agr., Agr. Res. Serv. Agr. Handb. United States Departm of Agriculture, Agricultural Research Service, Agricultural Handbo

U.S. Dep. Agr., Agr. Res. Serv. Rep. Chief Bur. Entomol. Pl Quar. United States Department of Agriculture, Agricultural search Service, Report of the Chief of the Bureau of Entomology Plant Quarantine.

U.S. Dep. Agr., Agr. Res. Serv. Rep. State Agr. Exp. Sta. United S Department of Agriculture, Agricultural Research Service, Repor the State Agricultural Experiment Stations.

U.S. Dep. Agr. Bull. United States Department of Agriculture Bull

U.S. Dep. Agr. Bur. Entomol. Bull. United States Department of culture, Bureau of Entomology, Bulletin.

U.S. Dep. Agr. Entomol. Rep. Entomol. United States Departme Agriculture, Bureau of Entomology, Report of the Entomologist.

U.S. Dep. Agr. Bur. Plant Quar. Serv. Reg. Announce. United S Department of Agriculture, Bureau of Plant Quarantine Service Regulatory Announcements.

U.S. Dep. Agr. Circ. United States Department of Agriculture Circ

U.S. Dep. Agr. Farmers' Bull. United States Department of Agricu Farmers' Bulletin.

U.S. Dep. Agr. Misc. Publ. United States Department of Agricu Miscellaneous Publication.

Univ. Calif. Publ. Tech. Bull. University of California Publica Technical Bulletin.

. Hawaii Coop. Ext. Leafl. University of Hawaii Cooperative Extension Leaflet.

. Iowa Stud. Natur. Hist. University of Iowa Studies in Natural istory.

oria J. Agr. Victoria Journal of Agriculture.

n Isl. Agr. Exp. Sta. Bull. (St. Croix). Virgin Islands Agricultural periment Station Bulletin (St. Croix).

Polytechnic Inst. State Univ. Res. Div. Bull. Virginia Polytechnic stitute and State University Research Division Bulletin.

Waite Agr. Res. Inst. Rep. (Univ. Adelaide). Waite Agricultural Research Institute Report (University of Adelaide).

West Indian Bull. West Indian Bulletin.

West. Aust. Dep. Agr. Annu. Rep. Western Australia Department of Agriculture Annual Report.

Zashch. Rast. (Leningrad). Zaschita Rastenii (Leningrad).

Z. Vergl. Physiol. Zeitschrift für das Vergleichende Physiologie (Berlin)

Z. Wiss. Insektbiol. Zeitschrift für Wissenschaftliche Insektenbiologie (Berlin).

(38479—4000—3-72)

Biology

COMBINED CULTURE OF CHANNEL CATFISH AND GOLDEN SHINERS IN WADING POOLS

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RICHARD J. BAUR
CHARLES F. THOITS III
C. RUSSELL ROSE

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OIS NATURAL HISTORY SURVEY
, Illinois-April, 1972

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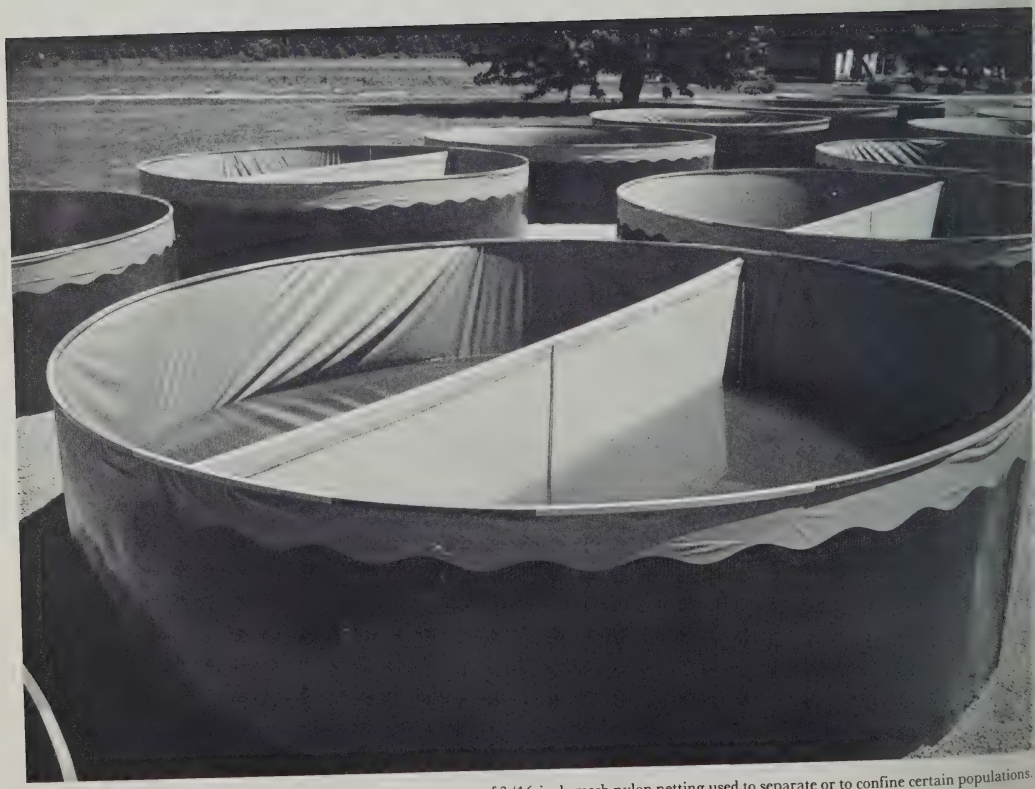

Fig. 1.—Ten-foot-diameter plastic pools with dividing screens of 3/16-inch-mesh nylon netting used to separate or to confine certain populations.

OMBINED CULTURE OF CHANNEL CATFISH ND GOLDEN SHINERS IN WADING POOLS

D. Homer Buck, Richard J. Baur, Charles F. Thoits III, and C. Russell Rose

E RAISING of golden shiners (*Notemigonus crysoleucas*) a bait minnow, and of channel catfish (*Ictalurus punctata*) as both a food and sport fish, has become an important ustry throughout most of our southern states. It has en customary to raise the two species separately, but re is increasing interest in combining the cultures. Mar- (1968) has listed various methods by which some grow- have combined the two on a limited basis, but he points that almost nothing exists in the literature about raising nows and catfish in combination.

This study was undertaken to provide information not available on the behavior, comparative efficiencies, degrees of compatibility of channel catfish and golden ers when in different combinations and under different ial limitations. The Java tilapia (*Tilapia mossambica*) also used in 1968 to measure the influence of such a d species upon its companion fishes; it was not used in 1969 experiments.

The project was provided major financial assistance by Bureau of Commercial Fisheries through the Commer- Fisheries Research and Development Act of 1964. The ies were conducted at the Sam A. Parr Fisheries Re- ch Center, Marion County, Illinois, which is a cooper- e facility of the Illinois Natural History Survey and the ois Department of Conservation. Thanks are due rge W. Bennett for his critical review of the early uscript. The final manuscript was edited by O. F. Glis- orf, technical editor, and the cover design was prepared loyd LeMere, technical illustrator, at the Natural His- Survey.

MATERIALS AND METHODS

l major experiments were conducted in 1968 and 1969 astic pools 10 feet in diameter and 30 inches deep. ted observations were made in aquariums. Some pools fitted with dividers (Fig. 1), which permitted the ical association or separation of the species, as desired, also provided variations in spatial densities. Such di- s were constructed of 3/16-inch-mesh nylon netting on es of galvanized tubing. The netting permitted a circu- n of water and distribution of metabolites or other rborne products throughout the pool area.

all outdoor experiments in both years all pools were ded a substrate of light sandy soil. In all pools to be in an individual experiment the soil substrates were ulously standardized in two steps—pulverizing dried soil to the fineness of fine sand by passing it through a mill designed for grinding livestock feeds, and thorough mixing in a cement mixer. Each lot of mixed soil was evenly divided among all pools. Each received about 6.5 cubic feet of mixed soil, sufficient to cover the bottom to a depth of about 1 inch.

Water used in all experiments was pumped from a 3.5-acre pond. All fish populations were seined and weighed every 14 days and the weights were used to establish new feeding levels. Shiners received their food in the form of a meal; catfish were fed small pellets. Turbidities, dissolved oxygen, pH, free CO_2, alkalinities, and ammonia (NH_3) were monitored twice weekly, usually in the late morning. Outdoor pools were not shaded, and summer temperatures of surface waters were recorded as high as 96° F.

INDOOR EXPERIMENTS IN 1968

Culture in Plastic Pools

Methods.—Our initial experiment ran from January 11 to May 24, 1968, a period of 134 days. In partitioned 10-foot-diameter plastic pools we stocked channel catfish and golden shiners in two ways (Fig. 2). In one pool the two species were physically separated (two groups of each species, four partitioned areas) but shared the same water circulating through the separating nylon screen. In a second pool the species were physically associated (two mixed groups, two partitioned areas). Total areas and water volumes in the two pools were similar, and total numbers (100 catfish, 450 shiners) and initial weights of each species in each pool were equal. Also, over the course of the experiment each pool received the same total amount of food. Actually, original stock on January 11 included only 15 catfish in each group (30 in each pool), but on January 19 the numbers were increased to 50 in each group (100 in each pool). These final densities were equivalent to about 55,500 catfish and 250,000 shiners per acre. Individual

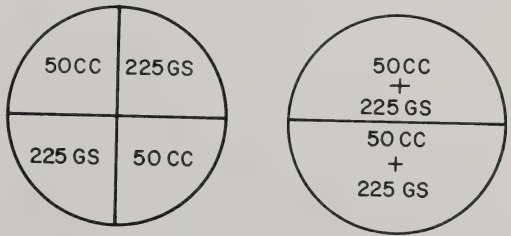

Fig. 2.—The partitioned circles illustrate the manner in which the pools used in the indoor experiments were divided by nylon screens to permit a mixing or separation of the groups of 50 channel catfish (CC) and 225 golden shiners (GS).

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weights when stocked averaged 1.68 grams for catfish and 1.31 grams for shiners.

Each pool was lighted by a 300-watt incandescent bulb from 6 a.m. to 5 p.m. Because the space available to these experiments was poorly heated, water temperatures could be maintained no higher than from 72 to 75° F. Both pools were continuously aerated and small submersible pumps assured a continuous, slow circulation of water throughout the pools.

Results.—After 134 days, standing crops in the two divided pools were equivalent to 2,709 pounds per acre (1,838 pounds of shiners, 871 of catfish) where the species were mixed, and 2,555 pounds per acre (1,942 pounds of shiners, 613 of catfish) where the species were separated, having increased from original stocks equivalent to about 920 pounds per acre (720 pounds of shiners, 200 of catfish). This was considered to be a good production rate for shiners, but catfish growth was limited by water temperatures that never exceeded 75° F.

Fish behavior was observed daily over about the first 30 days, after which visibility was limited by high turbidity. Normal shiner behavior appeared to be a slow, continuous, seemingly aimless movement in a loose school. When in the same water with catfish the two never mixed except when feeding; the catfish remained at the bottom, and the shiners were in the upper waters. However, when both fed on meal that had sunk to the bottom, they fed and intermixed in an apparent state of harmony.

Catfish behavior changed somewhat with time and increase in density, and was different when the catfish were and were not mixed with shiners. Initial populations of 15 channel catfish were exceedingly nervous, and when not darting wildly about or attempting to hide at the base of the divider screen they clustered in a corner, suspended vertically at mid-depths by slow, continuous tail movements, an activity which we called "tailwalking." Those catfish not associated with shiners tailwalked in the corner quite continuously during daylight hours and were not observed to feed. Those mixed with shiners appeared calmed by the association, tailwalked less, and fed readily. At the first feeding on January 12, the shiners fed vigorously as soon as the meal hit the surface of the water, and when the meal had sunk to the bottom and was being "picked" by the shiners, the catfish joined them, feeding slowly and steadily, freely intermixed with the shiners. The catfish reformed their school when the feeding period was ended. At such times there appeared to be no species discrimination and no antagonism whatsoever between species or individuals.

A significant change in the behavior of the catfish occurred after the numbers were increased from 15 to 50. The 50 catfish almost continuously maintained their school while feeding, sweeping quite rapidly about and appearing to "feed on the run." The school was never observed to disband and the individuals to feed leisurely while intermixed with the feeding shiners, as they had done when they formerly numbered only 15. The moving school occasionally caused minnows to scatter out of their path. These near-contacts, however, appeared to be inadvertent, and no overt antagonism or interference of the feeding of either specie was observed. The calming influence of the shiners upo the catfish was apparent when the populations were sam pled after the initial 2 weeks. The catfish not confined wit shiners had lost weight to the extent of about 15 pounds pe acre, while those with shiners had gained about 40 pound per acre. At the termination of the experiment, final stanc ing crops of catfish averaged 42 percent higher with shine than when physically separated but sharing the same wa ter.

Culture in Aquariums

Methods.—In a second indoor experiment we used ple iglass and screened containers of identical size (4.5 cub feet) to confine channel catfish in equal portions of one the 10-foot wading pools previously described. The plex glass container, or aquarium, was submerged in the pool that the confined fish were subjected to the same temper ture, light, and water volume as those confined by th screened enclosure, the difference being that the 3/16-inc mesh nylon netting permitted a circulation of wat through the screened enclosure. We proposed to compa growth and behavior of fish in both containers with grow and behavior of an identical number of fish free to mo about in the total area of the pool.

Concurrently we established similar experiments wi smaller enclosures submerged in a 40-gallon aquarium determine if the same response to crowding and the sar interspecific relationships were apparent in the small water volumes. Unfortunately, the use of such small en ronments containing clear water proved unsatisfactory, a the series did not progress to the use of both catfish a shiners.

In the first set of experiments we used eight catfish each of the three lots in the wading pool and four in each the three lots in the 40-gallon aquarium. In all cases t fish ate little, if at all, and lost weight. This study was t minated after 29 days.

In a second run in these environments we increased number of fish to 24 in each lot in the pool and to 12 in ea lot in the aquarium.

Results.—In the aquarium trials all lots again l weight, and that phase of the project was terminate These and earlier tests in aquariums seemed to illustr that catfish confined alone in small containers filled w clear water do not behave normally, remain nervous, a eat poorly. Tests under such conditions are impractical. contrast, we have observed that upon transferring catf from a clear aquarium containing only catfish to an ad cent aquarium, also clear but containing tilapia, or tila and carp, the catfish became calm and began to feed w and grow. The presence of another species of fish appea to calm, and instill a sense of scurity in, the catfish.

The wading pool experiment involving three lots of fish each was terminated on May 3, after 79 days, with results shown in Table 1. The greater growth of the enclosed by glass, with no water circulation, was unexpe ed. A possible explanation was that the limited volume water in the glass enclosure became quite turbid with fe

Table 1.—Original and final weights and gains over a 79-day eriod for three lots of channel catfish under different conditions f confinement in a 10-foot-diameter plastic pool. The pool was aintained indoors.

ype of opulation	Weight (grams)			
	When Stocked	At Final Census	Gain	Percent Gain
ee in pool	47.4	66.0	18.6	39.2
nfined by net	45.4	60.0	14.6	32.2
nfined by glass	41.0	70.0	29.0	70.7

d wastes, whereas the other waters remained clear. It is sumed that catfish obscured in the darker, turbid water ere less nervous and were able to make more efficient use available foods than their companion lots in the clear ter. Concentrations of ammonia went to a maximum of ppm in the glass enclosure and averaged 0.83 ppm for readings over the experimental period; in the open pool maximum was 0.34 ppm with an average of only 0.16. e greater concentration of ammonia in the glass enclo- e occurred at relatively low pH values (mostly between and 8.0) and apparently had no limiting effects.

OUTDOOR EXPERIMENTS IN 1968

st Series

Methods.—The first series of outdoor experiments in- ved 20 pools containing two replications of each of 10 perimental populations, as illustrated in Table 2. The ols were arranged in three rows, with a separation of ut 2 feet between pools. The location of individual pop- tions within the arrangement of pools was established random selection. Water was maintained at a depth of ut 21.6 inches, providing a volume of about 1,057 gal- s. The pools were provided with soil substrates, as pre- usly described.

Average total lengths and weights of the fishes when ked were about 140 mm and 19 grams for catfish, 57 and 1.32 grams for the shiners, and 66.1 mm and 5.09 ms for the tilapia. A ration equal to 3 percent of the ght of the fish was fed once each day for 5 or 6 days each k. The pools were stocked over the 3-day period June 20, 1968 (catfish on June 18 and 19, and shiners and ia on June 20) and the study was terminated on Sep- ber 11. Thus the growing period ranged from 83 days shiners and tilapia to 85 for catfish, but for practical poses it has been computed as 84 days for all species.

esults.—Catfish mortalities were either catastrophic, hen oxygen was depleted, or insignificant. In both ulations in which 16 catfish were intermixed with shin- and in one where 16 catfish were separated from the ers by a screen, total mortalities were suffered too late e experiment for the fish to be replaced, and no final us data could be recorded (Table 2). Among the 13 ulations that provided usable data, only 10 catfish were rved dead and replaced during the experiment. All 13 ese populations were intact, containing either 8 or 16 iduals, at the termination of the study.

iner mortalities were high following initial stocking, gradually lessened over the first 30 days, and were quite insignificant thereafter. Rates of mortality were similar in all populations. Dead shiners floated and were replaced daily where separated from the catfish, but were not missed or replaced until the time of the biweekly sampling period when they were mixed with the catfish. If the shiners were eaten by the catfish, it probably occurred after the shiners had died, because mortalities were again approximately equal in all populations during the later period when very few deaths occurred in any pools. It seems unlikely that the catfish would have preyed upon living shiners during the first month but not in the last two. Growth curves do not indicate that the catfish mixed with shiners had a greater advantage during than after the period of high shiner mortality.

Our production data gain some perspective in Table 2, which presents final standing crops of all populations in terms of pounds per acre, together with the ranges and seasonal averages of pH, turbidity, ammonia, carbon dioxide, and total alkalinity. These data show that (1) standing crops of catfish were highest in weight when they were maintained alone in an entire pool, but only about 10 percent higher than when the same numbers of catfish were confined to one-half of a pool or when mixed with shiners and tilapia in an entire pool, (2) standing crops of shiners were consistently and significantly (.05 level) higher in weight when in direct association with catfish, or with catfish and tilapia, than when maintained alone, as emphasized by the fact that 45 shiners mixed with catfish made a greater gain than 90 shiners maintained alone, (3) shiners and tilapia increased total fish production while scarcely affecting catfish production, and (4) when all three species were combined at the lower stocking rate of 8 catfish and 45 shiners, mean production of catfish was about 14 percent higher and total production was 42 percent higher than in mixtures containing only catfish and shiners.

In Table 2 we may also observe that in general the highest production by both catfish and shiners occurred in those pools having the highest levels of turbidity, ammonia, and carbon dioxide. We suspect that the higher levels of ammonia and carbon dioxide were the result, rather than the cause, of higher fish production. It seemed clear, however, that both fish density and turbidity influenced production and that the two were inseparably related. Catfish production appeared to be most strongly influenced by density or availability of space, while shiners appeared to be more strongly influenced by turbidity or density of phytoplankton. For example, gains by catfish having access to entire pools were always higher than gains by similar numbers confined to halves of pools; these differences were significant at the .05 level. On the other hand, gains by shiners were greatest where turbidities were greatest, regardless of whether they had access to all or only one-half of a pool, and this correlation ($r = .901$) between high shiner production and high turbidity was significant at the .01 level.

It was additionally clear that high turbidity occurred only in the presence of catfish. The level of turbidity was related more to the area of bottom available to the catfish than to the number of catfish, the presence or absence of

TABLE 2.—Means of final standing crops for channel catfish (CC), golden shiners (GS), tilapia (T), and all species combined (All), i 10-foot-diameter plastic pools, compared with ranges and seasonal averages of pH, and of parts per million of turbidity, ammonia, ca bon dioxide, and total alkalinity. The pools were maintained outdoors over an 84-day growing period, with two replications for each typ of population.

Type of Population [a]	Final Weight (lbs/A)				Range (in parens) and Seasonal Average				
	CC	GS	T	All	pH	Turbidity (ppm)	NH_3 (ppm)	CO_2 (ppm)	Alkalinity (ppm)
16/90 [b]	..	438[d]	..	438	(7.2–10.0) 8.1	(8–220) 76	(0.04–.97) 0.41	(0–18.1) 5.2	(56–123) 80.0
16/90 [c]	884[d]	381[d]	..	1,265	(7.5–10.0) 8.3	(7–106) 46	(0.01–.72) 0.31	(0–9.5) 2.7	(57–100) 70.5
16/90/10	1,012	447	588	2,047	(7.4–10.0) 8.2	(3–295) 85	(0.04–1.61) 0.44	(0–13.3) 3.9	(52–113) 75.1
16	1,111	..	..	1,111	(7.4–10.1) 8.2	(5–210) 60	(0.00–.96) 0.33	(0–9.3) 3.4	(57–99) 71.4
16	1,011	..	..	1,011	(7.5–10.1) 8.3	(2–92) 34	(0.00–.60) 0.27	(0–10.4) 3.3	(59–98) 72.9
90	..	258	..	258	(7.8–9.9) 8.3	(0–32) 16	(0.00–.46) 0.19	(0–12.4) 3.1	(55–85) 67.7
90	..	226	..	226	(7.3–9.4) 8.3	(0–19) 8	(0.00–.47) 0.17	(0–6.9) 2.5	(57–84) 66.8
8/45	560	294	..	854	(7.4–10.0) 8.2	(7–150) 55	(0.00–.83) 0.34	(0–10.8) 3.8	(57–115) 74.8
8/45	460	171	..	631	(5.7–9.5) 8.4	(4–60) 27	(0.04–.60) 0.23	(0–6.9) 2.2	(57–97) 67.0
8/45/5	637	237	338	1,212	(7.4–9.9) 7.8	(1–196) 65	(0.00–.80) 0.50	(0–13.3) 3.5	(57–110) 72.0

[a] Populations contain shiners in lots of 45 or 90, catfish in lots of 8 or 16, and tilapia in lots of 5 or 10.

[b] Designates pool containing 16 catfish and 90 shiners intermixed.

[c] Designates pool containing 16 catfish separated from 90 shiners by a net.

[d] Data from one pool only due to excessive mortalities in its replicate.

shiners, or the amount of food received by the pool. For example, turbidities were consistently higher in those pools having only catfish, but where the catfish had access to all of the pool bottom, than in a) the pools where the same numbers of fish received the same amount of food but were restricted to one-half the pool, or in b) those pools where the same number of catfish were restricted to one-half the pool but where food received was greater due to the presence of 90 shiners in the other half. In these instances, turbidities were due primarily to densities of phytoplankton, and these greater densities were believed related to the interaction of the catfish with the bottom mud. Stirring of the bottom by catfish did not muddy the water but it was probably sufficient to increase the release of soil nutrients into the water for use by phytoplankton. The shiners therefore appeared to gain an indirect benefit from their association with catfish due to the greater production of phytoplankton associated with the catfish.

Also of interest were the differences in food conversion ratios and their relationship to turbidity. Conversions we computed on the somewhat vulnerable assumption th each species ate only its assigned ration—pellets for the c fish and tilapia, and meal for the shiners. While the sumption cannot be completely true, the data are noneth less informative.

Table 3 presents all conversion statistics for which da are available. At the higher density levels the most efficie conversion ratios by catfish occurred in those pools conta ing only catfish and having intermediate (34–60 ppm) tu bidities (Table 2), whereas the least efficient conversions shiners were in those pools containing only shiners a having very light turbidities (8–16 ppm).

In those pools containing both catfish and shiners, co versions by catfish were slightly, but not significantly, lo er when mixed with shiners than when separated fr them by a net, whereas conversions by shiners *were* sign cantly lower (1) when mixed with catfish than when sep ated from them by a net, (2) when separated by a net

Table 3.—Mean conversion ratios of artificial feeds by catfish, shiners, and tilapia, each species individually and the species combined, over two time intervals and under different types of association and confinement for two replications of each type population. Species are designated as: CC = channel catfish, GS = golden shiners, T = tilapia. All indicates a combination of all species. The populations were maintained outdoors in 10-foot diameter plastic pools.

Type of population[a]	7/16/68–8/13/68			7/16/68–9/11/68			
	CC	GS	All	CC	GS	T	All
16/90[b]	1.55	0.88	1.31	..	..	..	..
16/90[c]	1.73	1.85	1.76	..	..	..	..
16/90/0	..	..	..	1.98	1.03	0.65	1.22
16/0	1.44	..	..	1.78	..	..	..
16/0	1.51	..	..	1.65	..	..	..
90/0	..	..	..	..	2.52	..	..
90/0	..	..	..	..	3.02	..	..
8/8	1.09[d]	0.62[d]	0.91[d]	..	..	..	..
8/8	2.09	2.37	2.14	..	..	..	..
8/8	..	..	..	1.50	1.05	0.53	1.07

[a] Populations contain shiners in lots of 45 or 90, catfish in lots of 8 or 16, and tilapia in lots of 5 or 10.
[b] Designates pool containing 16 catfish and 90 shiners intermixed.
[c] Designates pool containing 16 catfish separated from 90 shiners by a net.
[d] Data from one pool only due to excessive mortalities in its replicate.

ing the same water than when in a pool alone, and (3) n mixed with catfish than when in a pool alone.

should be noted, however, that turbidities due to phy- ankton were also consistently highest where the two es were in direct association and where the catfish had ss to the entire bottoms of the pools. This suggests that igher turbidities favored both species and that the rs probably gained a part of their sustenance from the plankton which caused the higher turbidities.

nd Series

ethods.—A second series of outdoor experiments was ned as a homogeneity study to measure the variations fish production within and between pools and to de- ne if the presence of the divider screen and the conse- confinement of the fish to a smaller area (while main- g the same density) had in itself any measurable in- e upon production. It involved only fed catfish in pools. Each pool was stocked with 16 catfish (8,880 re), but four pools were divided into equal halves by netting, and equal numbers (8) were placed on each the dividing screen. The catfish were from the same d of the same size as those stocked in the outdoor previously discussed and were fed at the same rate. However, only three divided and three undivided pools produced useful data because of excessive mortalities in one population and the intermixing of the divided populations in a second pool.

Results.—There was no mortality in the six pools which provided usable data, and the final standing crops ranged from 927 to 1,110 pounds per acre, with a mean of 1,026. There was no significant difference (.05 level) in the pounds of catfish produced in the six pools, indicating that the existence of the dividers and the confinement of the catfish to half the pool area had no influence on catfish production.

The average final standing crop in these six pools, 1,026 pounds per acre, was very similar to that of 1,061 obtained concurrently in the four pools in our other series which contained catfish only.

DISCUSSION OF 1968 EXPERIMENTS

Results from the indoor experiments differed from those obtained in outdoor pools because of the great differences in the experimental environments. The indoor pools contained no soil substrates, foods eaten were entirely artificial, and the water was maintained at a constant temperature of 72–75° F., which is below that considered optimum for growth of either catfish or shiners. The outdoor pools contained a soil substrate which, when "worked" by catfish, contributed to the dense blooms of phytoplankton, which in turn contributed to the diet of both shiners and tilapia. Additional foods for the outdoor fishes included terrestrial insects which at times entered the pools in substantial numbers, as well as a large complement of aquatic insects, including mayflies, dragonflies, and a variety of midges, which very quickly colonized the outdoor pools and began reproducing. There were also substantial differences in fish densities in the indoor and outdoor populations.

Final standing crops of shiners in the indoor pools greatly exceeded those produced outdoors, while the outdoor production of channel catfish greatly exceeded that produced indoors. Greater production of shiners indoors was due in part to the greater density per pool (400 vs. 90) and to the longer growing period; but greater weights of channel catfish were produced outdoors in spite of a much lesser density (16 vs. 100) and a shorter growing period. Factors contributing to the greater production by catfish outdoors probably included higher water temperatures and the availability of natural foods.

The presence of shiners and tilapia caused little or no loss of catfish production in the outdoor pools. Poor production by catfish indoors suggests that growth may have been inhibited by the high density of shiners, although low water temperatures were also important.

The much greater production of shiners indoors indicated that growth was inhibited very little by the combination with a dense population of catfish, by the relatively low water temperatures, or by the higher levels of ammonia and carbon dioxide in the indoor pools.

The degree of behavioral and physiological compatibility of the catfish and shiners in the densities here employed may be inferred partly by direct, but largely by indirect, evidence. We pointed out earlier that no antagonistic be-

havior was ever observed in the mixed populations in the indoor pools. A high degree of compatibility among the outdoor populations was indicated by the fact that (1) shiner production was greater in mixed populations than when shiners were alone and (2) the presence of tilapia and/or shiners did not limit catfish production.

Direct observations of the species when mixed in the outdoor pools were limited by the tendency of the catfish to hide when the water was clear enough for good visibility, and by phytoplankton blooms. All species normally fed at the surface, but catfish maintained alone were sometimes slow to rise to the food. When mixed with tilapia, however, they commonly rose immediately and competed vigorously with the tilapia for the food. Coexisting shiners stimulated the same response but to a lesser degree. All three species were stimulated to a faster and more vigorous feeding response when associated than when alone and able to feed at their leisure, and such stimulation led to a more efficient use of food.

EXPERIMENTS IN 1969*

First Series

Methods.—Our first series in 1969 involved 21 pools having three replications of each of seven types of populations. The catfish were stocked on May 29 and the shiners on June 4, 1969. We used two levels of densities which doubled those used in 1968. The maximum populations of 32 catfish and 180 shiners were equivalent to 17,760 catfish and 99,900 shiners per acre. The two species were again separated in some pools and mixed in others, as illustrated in Table 4.

Mean weights of fish in the original stocks were about 2.73 grams (173 per pound) for shiners and about 13.0 grams (35 per pound) for catfish. Final censuses were made on September 10, 1969, providing growth periods of 104 days for catfish and 98 days for the shiners. Tilapia were not used in 1969 because they were not essential to the study. Again, the catfish received pellets and the shiners received meal. All fish were fed twice a day for either 5 or 6 days each week at a total daily ration approximating 3 percent of their weight. The populations were sampled by seine, and fish weights were measured every 14 days. All pools received nearly continuous aeration.

Results.—Table 4 presents the average final standing crops in replicated pools for the two species, both individually and combined, along with seasonal ranges and means of various environmental parameters. Data for some populations were unusable because of excessive mortalities, due principally to failures in aeration, but usable data were obtained from at least two replications of each of the several experimental populations. We had believed that in doubling the densities we would assure that carrying capacities would be attained prior to our termination of the experiments in September, but an inspection of the growth curves in Fig. 3 shows that rates of growth had not declined b

*All 1969 experiments were conducted in outdoor pools.

TABLE 4.—Means of final standing crops, in pounds per acre, for various mixed and unmixed populations of channel catfish (CC) and golden shiners (GS) when maintained outdoors for about 100 days in 10-foot diameter plastic pools, together with ranges and means of pH and parts per million of turbidity, ammonia, and free carbon dioxide based on determinations made twice weekly over the same period.

Type of Population [a]	Usable Replications [b]	Final Weight (lbs/A)			Range (in parens) and Mean			
		CC	GS	Both	pH	Turbidity (ppm)	NH_3 (ppm)	CO_2 (ppm)
32 / 180 [c]	2	1,629	1,344	2,973	(7.20–9.00) 7.89	(48–340) 151	(0–1.90) 0.728	(0–17.62) 3.44
32 / 180 [d]	2	1,918	1,136	3,054	(7.49–9.01) 7.92	(18–410) 179	(0.17–1.31) 0.660	(0–12.86) 2.67
16 + 90 | 16 + 90	2	2,154	1,022	3,176	(7.31–8.80) 7.77	(34–600) 207	(0.30–1.97) 0.671	(0–12.38) 3.61
16 + 90 |	3	1,049	709	1,758	(7.42–8.30) 7.78	(2–57) 29	(0.05–.85) 0.413	(0–13.33) 3.37
16 / 90	2	1,238	687	1,925	(7.37–8.5) 7.84	(17–150) 89	(0.10–1.09) 0.523	(0–9.52) 2.22
32	2	2141	..	..	(7.40–8.84) 7.81	(8–211) 75	(0.13–1.26) 0.588	(0–9.52) 2.63
180	3	..	1,260	..	(7.35–8.88) 7.85	(14–260) 105	(0.04–1.47) 0.649	(0–11.43) 1.78

[a] Populations contain shiners in lots of 90 or 180 and catfish in lots of 16 or 32.
[b] Indicates whether usable data were available from two or three replicates.
[c] Designates pool containing 32 catfish and 180 shiners intermixed.
[d] Designates pool containing 32 catfish separated from 180 shiners by a net.

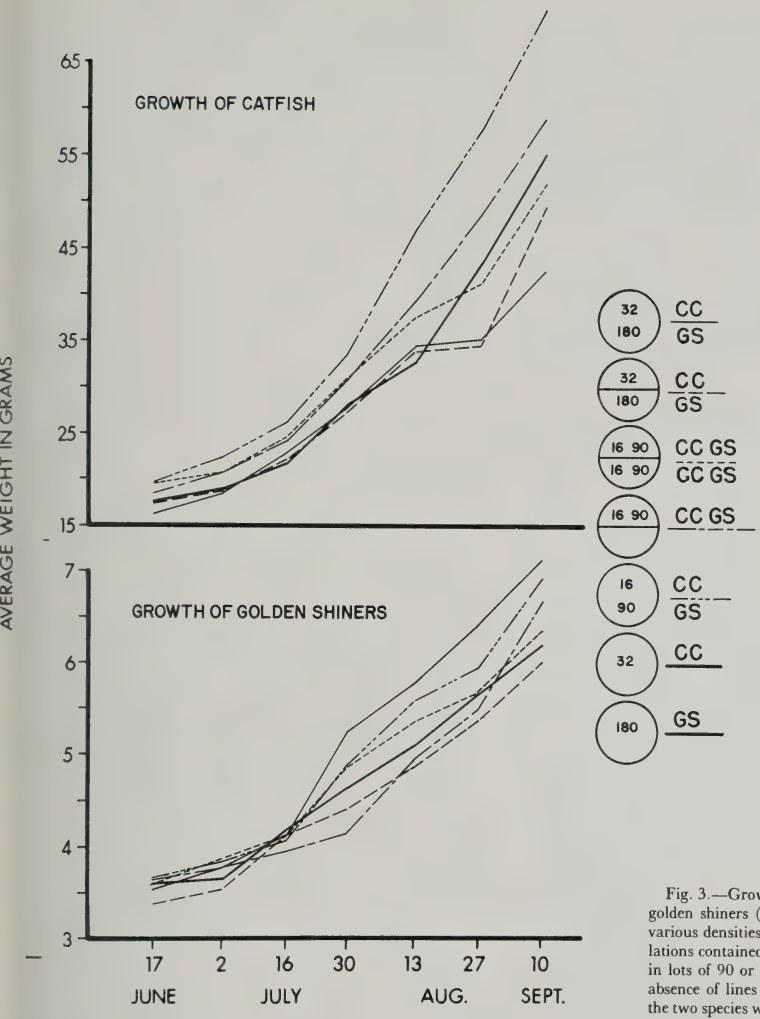

Fig. 3.—Growth curves for channel catfish (CC) and golden shiners (GS) held in 10-foot-diameter pools at various densities and degrees of association. The populations contained catfish in lots of 16 or 32, and shiners in lots of 90 or 180, as diagrammed. The presence or absence of lines bisecting the circles indicates whether the two species were mixed or separated.

eptember 10, even though standing crops were large. Maximum crops exceeded 2,000 and 1,000 pounds per acre or catfish and shiners, respectively, providing a weight of ver 3,000 pounds per acre where the species were combined. In these tests the highest standing crop of catfish ccurred when each half of a pool contained 16 catfish ixed with 90 shiners but was less than 1 percent greater an the final weight of 32 catfish alone in an entire pool. o significant differences existed in production by 32 catsh alone or when mixed with shiners.

As in our 1968 tests, the greatest production of shiners ccurred when the shiners were directly associated with atfish, but production was not significantly greater than iat by an equal number of shiners maintained alone in an qual volume of water. Perhaps the most impressive result of these experiments was that the total combined production by 32 catfish and 180 shiners when each was maintained alone in separate pools was not significantly larger than that made by the two species when combined in one pool.

In the 1968 tests high production by shiners was associated with high plankton turbidity, and high turbidity appeared to be related to the amount of pool bottom available to foraging catfish. In the more dense populations of 1969, turbidity was related more to numbers of fish than to the existence or activities of one or the other species. The factors which probably contributed most to the high turbidities in 1969 were the greater levels of feeding and of organic wastes in those pools containing the higher densities of both species.

Second Series

Methods.—In a series of eight pools we established two replications of each of four different populations that all contained the same total numbers of both species, but in four different degrees of association (Table 5). The objective was to gain additional information on species relationships and the influence of density. The pools received their initial stock on May 29, 1969, and were drained and censused on July 23, 1969, providing a growing period of 55 days.

TABLE 5.—Means of final standing crops, in pounds per acre, for two replications of each of four different combinations of channel catfish (CC) and golden shiners (GS) when maintained outdoors in 10-foot-diameter plastic pools over a 55-day growing period. Underlined quantities designate weights of those fishes mixed in the same half pool.

Type of Population [a]	Final Weight (lbs/A)				
	GS	GS	CC	CC	Total
32/180 [b]	734	..	1,000	..	1,734
32/180 [c]	754	..	864	..	1,618
90/90 + 32	379	363	1,003	..	1,745
16/16 + 180	..	700	537	391	1,628

[a] Populations contain shiners in lots of 90 or 180 and catfish in lots of 16 or 32.
[b] Designates pool containing 32 catfish and 180 shiners intermixed.
[c] Designates pool containing 32 catfish separated from 180 shiners by a net.

Results.—Among the eight shiner populations, differences in production were not significant between those confined in one-half of a pool and those occupying all of a pool, or between those directly associated with catfish and those sharing the same water with catfish but being physically separated from them by a screen. Differences in production between catfish populations were larger than those for shiners, but still not significant. The differences appeared related to predation of shiners by catfish, and this was the only experiment in which such predation was evident. Gains by catfish were consistently largest when the catfish were mixed with shiners, and the data in Table 6 show that numbers of unaccounted-for shiners were consistently larger where mixed with catfish. The differences were statistically significant.

Some calculations were made to provide a basis for evaluating the degree to which predation of shiners by catfish might have influenced production of the catfish. Using the mean final weight of shiners of 4.28 grams (which would be excessive for this computation), assuming that all unaccounted-for shiners were eaten by the catfish, and assuming a conversion ratio of 1 pound of catfish gain for 2 pounds of shiners eaten, predation of shiners would have accounted for about 67 percent of the difference in the final standing crops of catfish when mixed and when not mixed with shiners. We believe, however, that the actual contribution of the shiners was much less.

TABLE 6.—Numbers of golden shiners that could not be accounted for at time of final censuses after being mixed or not mixed with channel catfish over a 55-day period in 10-foot-diameter pools.

Type of Population [a]	Pool Number [b]	Number Unaccounted for	Mixed with Catfish
32/180 [c]	22	29	yes
	27	32	yes
32/180 [d]	23	5	no
	24	8	no
16/16 +180	28	39	yes
	29	41	yes
90/90 + 32	25 E	5	no
	25 W	13	yes
90/90 + 32	26 E	11	no
	26 W	19	yes

[a] Populations contain shiners in lots of 90 or 180 and catfish in lots of 16 or 32.
[b] "E" beside number indicates east half of pool; "W" indicates west half.
[c] Designates two pools, each containing 32 catfish and 180 shiners intermixed.
[d] Designates two pools, each containing 32 catfish separated from 180 shiners by net.

Third Series

Methods.—In this series we again used eight poo which had standardized bottom soils and were filled simu taneously with water from a common source. We attempt to minimize all environmental differences with the purpo of measuring those differences in production attributab purely to the physical association or separation of the t species. This was accomplished by the common mixing water between a pool containing only one of the two speci and a second pool containing both species freely mixe Mixing was accomplished by a slow pumping of the wat from one pool to another and returning the same volume siphon. The small submersible pumps used transferr water at a rate of about 48 gallons per hour and were erated 9 hours each day for 5 days each week. The prin pal environmental difference between the paired pools w the greater depth of about 1 inch in the pool receiving pumped water, which was necessary to keep the siphon operation. Such mixing was intended to minimize the ferences of such factors as turbidity, pH, temperatu ammonia, and dissolved oxygen between paired pools.

The pools received their initial stock on July 24, 19 and were drained and censused on September 16, 19 providing a growing period of about 54 days. Among eight pools we had two replications of each of two pair follows:

1. A pool containing 180 shiners alone sharing circu ed water with a pool containing 180 shiners mixed wit catfish.

2. A pool containing 180 shiners alone sharing circu ed water with a pool containing 32 catfish alone.

Results.—The results of these experiments are prese in Table 7 and may be summarized as follows:

1. The greatest productions by shiners (1,163 and 1

ABLE 7.—Numbers recovered and final standing crops, in nds per acre, for populations of channel catfish (32) and gold- hiners (180) when mixed or separated but sharing water cir- ted between populations. Pools having a common water circu- on are paired in the column at left. The populations were ntained outdoors in 10-foot-diameter plastic pools for 54 days.

ired Pop- ations and umbers in riginal Stock	Final Standing Crop			
	Golden Shiners		Channel Catfish	
	Number	Pounds	Number	Pounds
180	162	1,066	..	..
180 / 32	170	1,127	31	1,521
180	173	1,124	..	..
180 / 32	174	1,027	33	1,674
180	176	1,163	..	..
32	..	..	32	1,637
180	171	1,132	..	..
32	..	..	32	1,447

nds per acre) were in those populations maintained e in pools sharing circulated water with pools contain- atfish only; these averaged less than 10 percent greater their companion populations and were not significant- fferent from them.

Greatest production by catfish occurred in those pools containing shiners, but there was less than 5 percent rovement and this was not significantly greater than n catfish were separated but shared circulated water.

Near-equal survivals by shiners when mixed and not d with catfish showed that predation was not a factor is experiment.

ne pump and siphon arrangement was not completely ent in equalizing measured parameters in the paired s, but the similarities in standing crops among both d and unmixed populations rendered the failure unim- ant. These results completely substantiated those ob- d in tests previously described, namely, that at the ities used neither species limited production of the oth- hen mixed, and as many total pounds could be pro- d by a mixed population in a single pool as by the same numbers separated by species in two pools and fed ar rations.

OVERALL DISCUSSION

ur findings resembled those of Yashouv (1969), who d that growth increments of carp (*Cyprinus carpio*) tilapia (*Tilapia aurea*) in mixed culture sometimes eded those exhibited by either in monoculture.

ur studies demonstrated that, within the range of sizes densities used, the channel catfish, golden shiner, and ia (*T. mossambica*) were extremely compatible. When bined, each stimulated the other to a faster and stronger feeding response, which resulted in a more efficient conversion of food. No antagonistic behavior was observed, and evidence of significant predation of shiners by catfish occurred in only one of the six test series studied during the 2-year period. While predation of shiners might become important if larger sizes of catfish were used, in certain types of operations the predation might be minimal or otherwise unimportant. If shiners were the primary crop, the "bonus" production of catfish could more than compensate for such limited predation as might occur, and if marketable-sized catfish were the principal crop, it would be of small consequence if some of the supplementary crop of shiners were eaten.

There are two basic fish farming operations in which the two species could be combined:

(1) Mix shiner fry with catfish fry, with the purpose of producing salable minnows and fingerling catfish. The shiners could be spawned in the pond or introduced as matted eggs or fry. The channel catfish could be added as fry, and Martin (1968) has recommended that such fry be at least 1 inch long. It would be advantageous to introduce catfish and shiners in approximate known numbers so as to control the size of the minnows and catfish fingerlings grown in this operation.

(2) Mix shiner fry with catfish fingerlings, with the purpose of producing salable bait minnows and channel catfish large enough for the food or "fish-out" market. In such an operation Martin suggests that the catfish not be placed in the pond until the shiners have become advanced fry.

Our results in the wading pools suggest that each species could be treated as if it were being cultured alone, insofar as densities, feeding rations, and final standing crops are concerned. It should be remembered, however, that at the higher densities used in 1969, aeration was required to prevent oxygen depletion in the pools. The potential for such depletion was undoubtedly enhanced by the small size and shallowness of the pools which caused abnormally high water temperatures and unusually high densities of phytoplankton. Such a tendency might be less in ponds, but it still could be a problem if high densities of both species received normal rations in ponds having no water exchange. The problem could be eliminated by water exchange, and could be greatly lessened by taking extreme care not to overfeed the catfish and by feeding the shiners a reduced ration.

The unusual efficiency with which our shiners that were mixed with catfish appeared to be converting supplied fish meal into fish flesh suggested that they were gaining important and unmeasured nutrients from the abundant phytoplankton. If rich plankton blooms could be produced in the absence of full rations for shiners, production of shiners might be reasonably high with a minimum shiner ration while maintaining a normal production of catfish on normal catfish rations.

Two principal problems in such a combined culture would be the danger of oxygen depletion because of the increased organic load, as already discussed, and the difficulties in harvesting the shiners without mechanical injury

from the catfish. It seems reasonable to expect that a technique could be developed whereby the shiners could be trapped, baited, or otherwise removed with a minimum of contact with the companion species. If not, it would be important to assure that the catfish be enough larger than the shiners to permit their separation by mechanical grading. Martin (1968) has suggested that the crop of fingerling catfish not exceed 10,000 per acre to assure that they will grow large enough to be easily separated from the shiners.

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Biology

ILLINOIS BIRDS: Hirundinidae

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Biological Notes No. 80

ILLINOIS NATURAL HISTORY SURVEY
Urbana, Illinois—August, 1972

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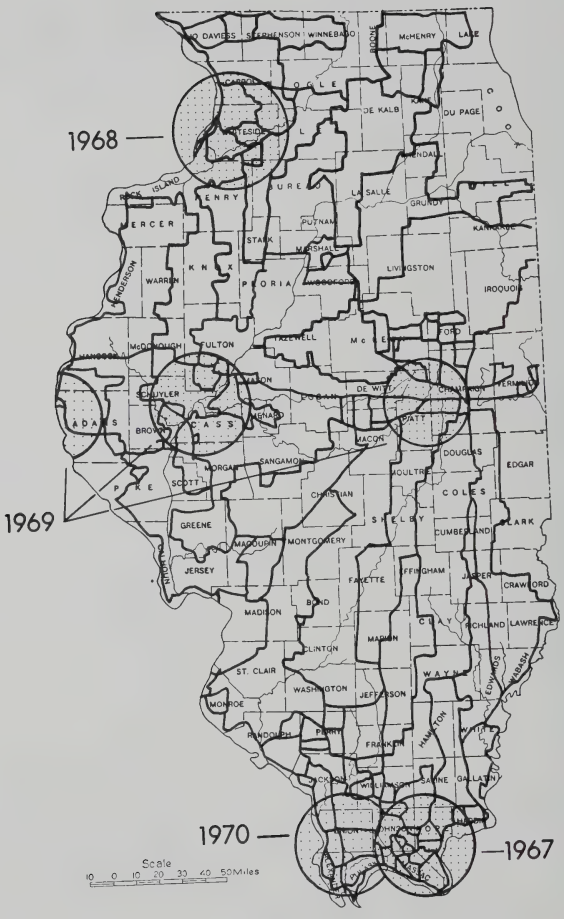


Fig. 1.—Routes travelled in summer (1957–1970) to study breeding distribution of the birds of Illinois. The encircled areas were special study areas where daily censuses of migrants and nesting populations of birds were carried out, 1967–1970.

INOIS BIRDS: Hirundinidae

Richard R. Graber, Jean W. Graber, and Ethelyn L. Kirk

THIS REPORT, the third in a series of papers on the birds of Illinois, deals with the ows. The introductions to the first two papers, he mimids and thrushes (Graber et al. 1970,) also serve as a general introduction to the s, and the procedures and policies outlined in papers also apply to this one.

ne point that warrants emphasis and clarifica- is the geographic scope of the papers. Unless wise indicated, the data presented and the ments made refer to the state of Illinois (Fig. 1), are not confined strictly within its political daries. In faunistic studies of this type, students lly confine themselves to politically defined , probably because (1) it is generally not fea- for one student, or several students working to- r, to study the whole world or even a continent, (2) political units are generally well known, y defined, and reasonably stable areas to at- t to cover. More than most states, Illinois has and limits marked by natural waterways, no- Lake Michigan and three major rivers. The northeastern boundary of Illinois lies over half across Lake Michigan, and though we would y include the information, there are almost ird records of any kind from the vast aquatic of the state which lies beyond a mile or so from hores of Lake and Cook counties.

s to the rivers, their political definition varies one to another. Thus, the Ohio River is con- ed to be Kentucky, while the Mississippi River, place to place, is Illinois, Missouri, or Iowa, the Wabash River is, similarly, Illinois or In- a. The biology of many species of birds is gly influenced by these bodies of water. Among wallows, for example, migrant populations are rally much higher along, or over, the major s, than away from them. Also, the great roosts rple martins in the St. Louis area have, through years, been located on both the Illinois and ouri sides of the Mississippi River. In our rts, therefore, we have included data from both s of the boundary rivers.

We hope that all students will be im- ed by the paucity of the presently available ledge on the birds of Illinois, and will thus ncouraged to fill in the great gaps. The swal- being generally colonial or semicolonial, are a particularly interesting group for distribution studies, and to determine their population trends we should know the location of every major colony or population in the state. We therefore appeal to all students of Illinois birds to examine the maps showing breeding distributions, and publish any additional information they may have. By this procedure we will ultimately learn the true distribution of all the Illinois species.

In bringing together the available information on the swallows we have received help, especially in the form of contributions of data, from many persons. We should particularly acknowledge John Schwegman of Vienna, Peter C. Petersen, Jr. of Davenport, Iowa, Peter Dring of Willow Springs, Loraine W. and James Funk of Liberty, Richard A. Anderson of St. Louis, Missouri, Sarah Vasse of Brussels, Elton Fawks of Moline, L. Barrie Hunt of Charleston, Mrs. Harry Shaw of Sterling, Lee G. Johnson of Rockford, Edwin C. Franks of Macomb, Dale E. Birkenholz of Normal, Miss Elda Goodmiller and Mrs. Glenn Williams of Elizabeth, Maurice L. Reed of Dixon, Mrs. Marian Cole of Deerfield, Ellen A. Hopkins and H. David Bohlen of Springfield, Michael D. Morrison of Sparta, Mahlon K. Mahoney of Kankakee, and Frank C. Bellrose and Robert Crompton of Havana.

Donald Webb identified chironomid fly specimens for us, and Lewis J. Stannard and R. Weldon Larimore provided data and references on the parasitism of cliff swallows by ticks. The staff of the Natural History Survey's Wildlife Research, Editorial, Art, and Photographic offices all made valuable contributions in the final preparation and editing of the manuscript, and in production of the drawings and photographs.

VIOLET-GREEN SWALLOW *(Tachycineta thalassina)*

This western species is included in the Illinois bird list on the basis of a single adult male specimen taken May 4, 1897 by George F. Clingman in the Calumet region of Chicago, an accidental record (Woodruff 1907, and Coale 1925).

TREE SWALLOW *(Iridoprocne bicolor)*

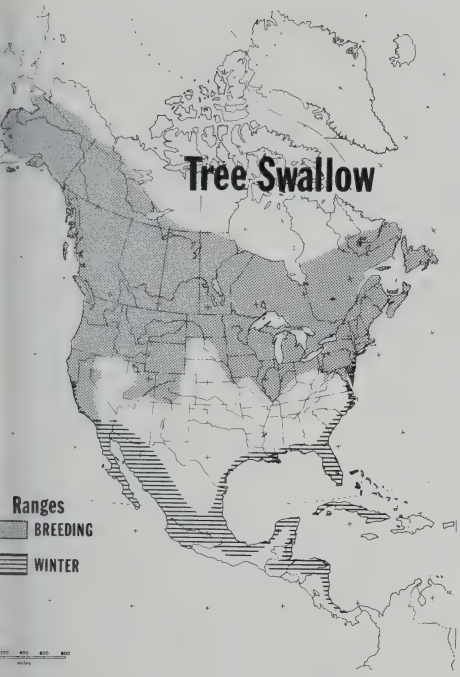
(Fig. 2 and 3)

Spring Migration

The Illinois literature contains no descriptions of the actual migration flights of tree swallows, and whether they are diurnal or nocturnal is unknown.

is paper is published in part with private funds and by authority State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from tion of Wildlife Research of the Illinois Natural History Survey. chard R. Graber is a Wildlife Specialist at the Survey. Dr. Jean W. is a Research Assistant Professor of Animal Science at the Univer- Illinois. The late Miss Ethelyn Kirk served as Technical Assistant Section of Wildlife Research at the Survey.

Fig. 2.—Tree swallows in August. The adult (below) is in badly worn plumage and molting; the immature (above) is in plumage. (Adults have metallic blue-green backs, immatures have gray-brown backs, but in all the underparts are immacul nearly so.)



ig. 3.—General distribution of the tree swallow. The out- range may include large sections in which populations of pecies are thin or even absent because of the nature of the n and paucity of suitable habitat.

use swallows forage on the wing, it may be ult to differentiate migration flights from feed- lights.

n Illinois the swallows, including tree swallows, lly appear earliest in the river bottoms, and even weeks later in adjacent uplands. The ber of birds also tends to be higher in bottom- s. Tree swallows have been seen in Illinois as as March 11, and Nelson (1876–1877) refers eir arrival in numbers to northeastern Illinois March 20, but more typically they come in l and May (Fig. 4). Usually, only a few birds seen in March, and there is a small but no- pulse about April 1. The largest influx occurs mid-April to late April, with lesser peaks early to mid-May (Fig. 4). The migration extend into June some years, as Loucks ublished manuscript, 1892) mentioned 200 birds over the Peoria area on June 11.

bution

he general distribution of the tree swallow is n in Fig. 3. The Illinois distribution (Fig. 5) is not well known. The present records indicate that most of the Illinois population is in the northern half of the state. Musselman (1933) hinted that the Illinois River was the principal nesting area for the tree swallow in Illinois, and indeed there are many nest records from the Illinois Valley. Sloughs in the Mississippi, Ohio, and Wabash bottoms of southern Illinois offer much habitat that looks promising, but, in general, the southern half of the state has not been investigated for breeding populations of this species. Ridgway (1874) recorded a nesting population near Mt. Carmel, but no nests have been reported there in this century.

Nesting Habitats and Populations

Tree swallows nest in isolated pairs as well as semicolonially. The nesting habitat most often described is a swamp or marsh with standing dead trees in or near the water. In Marshall County, Barnes (1890) found the tree swallow confined to the Illinois river bottoms.

The nest is placed in a cavity in a stump or dead limb. At Mt. Carmel, Ridgway (1874) noted that the swallows especially utilized cavities made by downy woodpeckers *(Dendrocopos pubescens)* and Carolina chickadees *(Parus carolinensis)*. Tree swallows also readily use man-made nest boxes, and most of the recent nesting records are of this type, though tree swallows have not received nearly as much attention in Illinois as have bluebirds *(Sialia sialis)* and martins *(Progne subis)*. The discrepancy may be related to the more specialized habitat of the tree swallow. There are several new, large reservoirs in the state, and nest boxes placed near the shores of such bodies of water may attract tree swallows and thus have a marked effect on the state population.

The only published population measurements are those of Beecher (1942) who found 40 nests (occupied nest boxes) in about 28 acres of modified woodland in Lake County. He also recorded an extremely dense population of 20 occupied boxes on 100 square feet. These figures do not include foraging habitat, however.

The tree swallow, like other cavity nesters, is confronted with the problem of competition for nest sites. Nelson (1876–1877) observed fighting over a house between martins and tree swallows, with the martins dominating, but Beecher (1942) found no strife between the two species occupying two houses on the same post. Ridgway (1874) noted apparent competition for housing between prothonotary warblers *(Protonotaria citrea)* and tree swallows. Barnes (1912) attributed population decline of the tree swallow in Marshall County after 1890 to competition from the house sparrow *(Passer domesticus)*, and Loucks (1895) also mentioned house sparrow competition with the tree

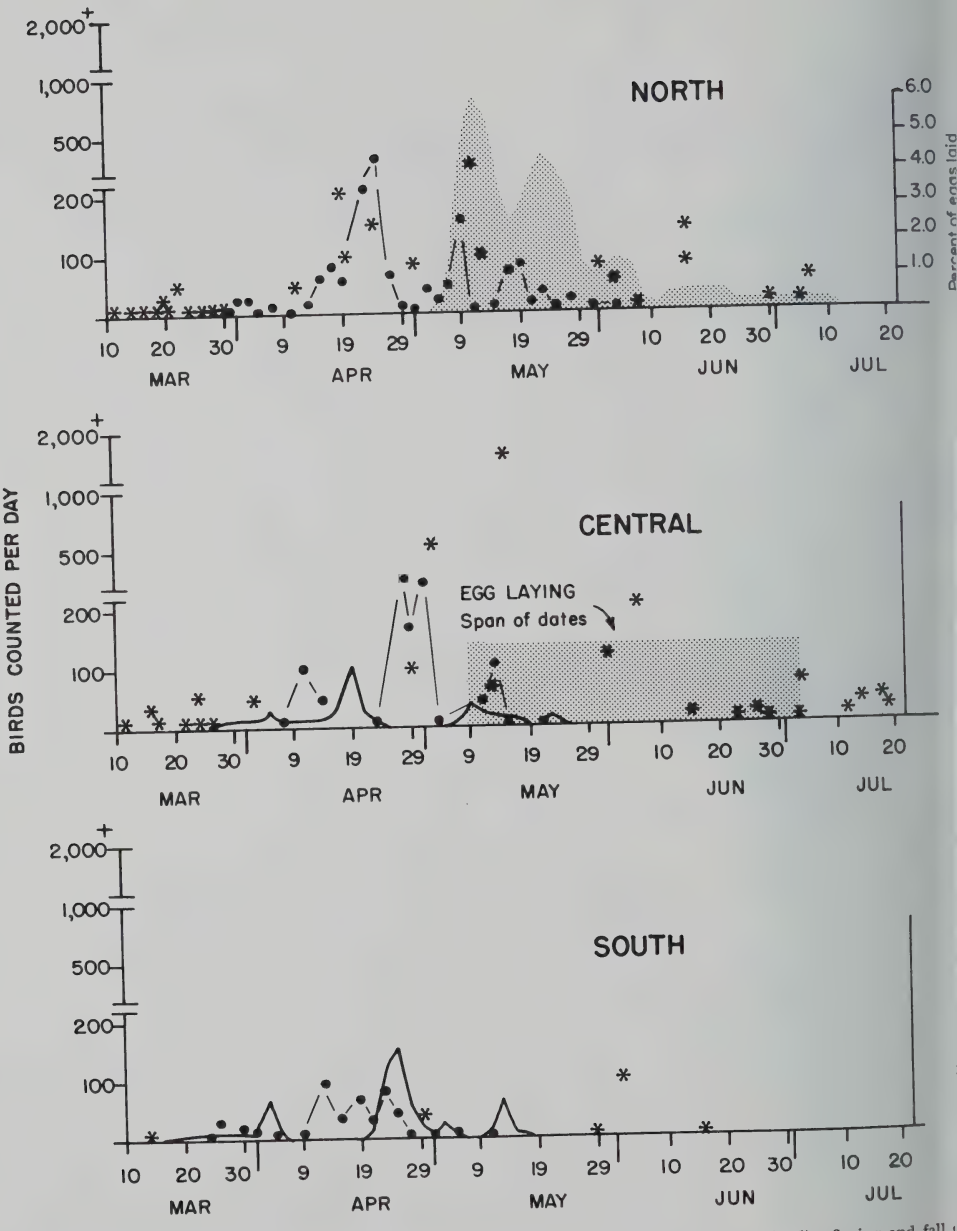
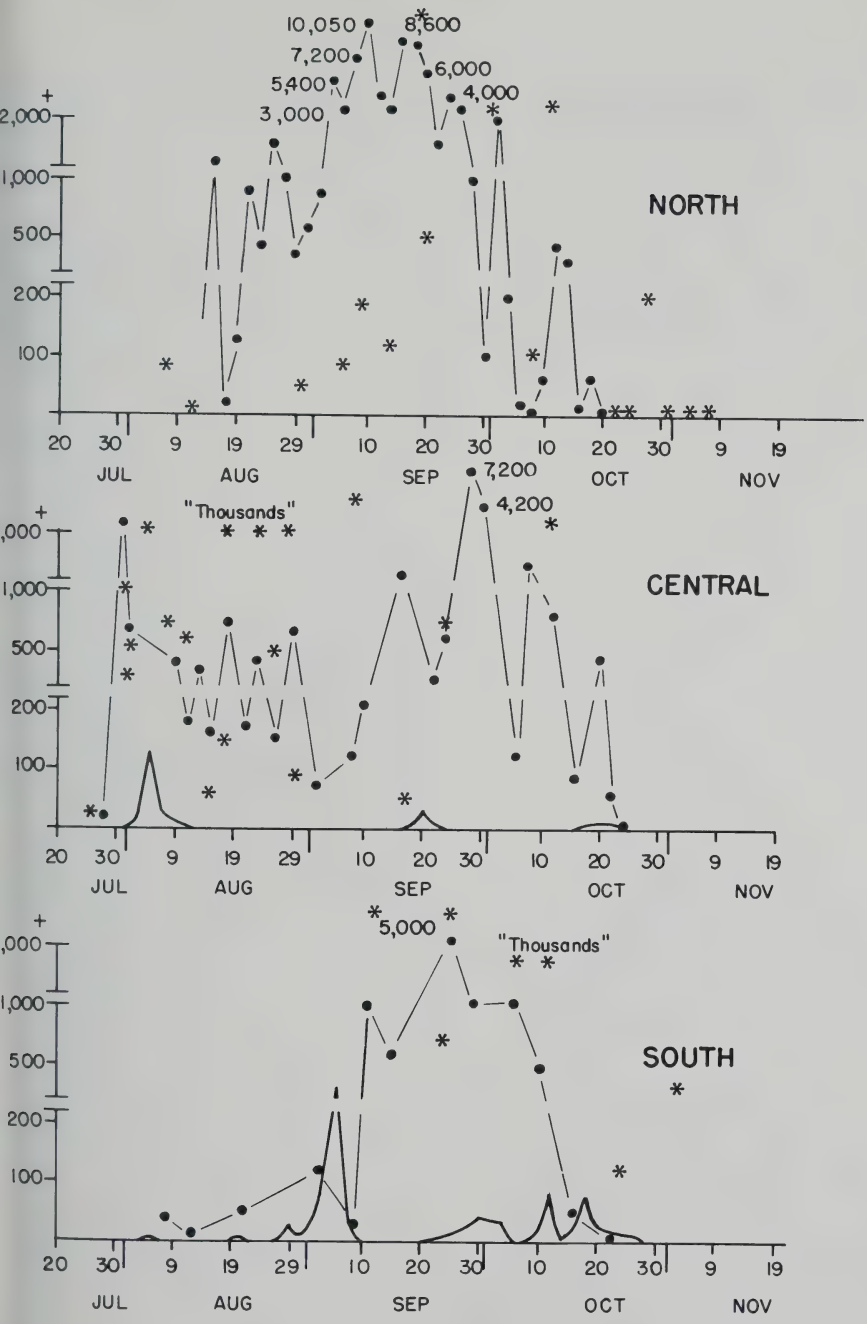


Fig. 4.—Egg-laying and migration seasons of the tree swallow in different areas of the state (see Fig. 1). Spring and fall
lines (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other
or by other observers. Shaded areas show the percent of eggs laid on a given date (right scale, North only) or the span of
during which egg laying has been recorded. Dot symbols represent counts made on the western side of the state; lines withou
represent the eastern side.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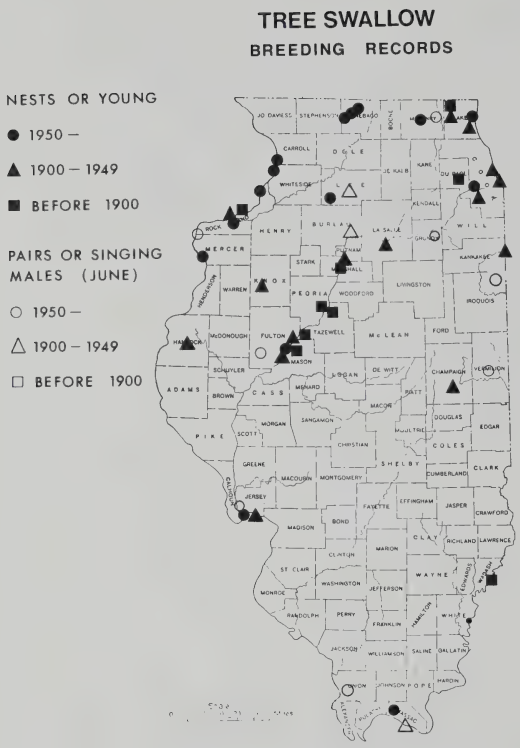


Fig. 5.—Breeding records for the tree swallow in Illinois.

swallow. John Schwegman (personal communication) noted that starlings *(Sturnus vulgaris)* took over cavities that tree swallows had used at Mermet Lake (Massac County).

Natural cavity nests have been recorded most frequently in willows, often stubs standing in water, with the nests 4–15 feet high.

Nesting Cycle

Very little has been published on the nesting cycle of the tree swallow in Illinois, though an excellent study by Peter Dring of Willow Springs is in progress. At present there are no published data on nesting success or productivity, and no data on any phase of the cycle from southern Illinois.

In Tazewell County, Loucks (unpublished notes, 1892) found tree swallows building nests as early as April 27. In the north most of the egg production comes in May, with laying starting as early as May 4, but some egg production occurs in June and July, as late as July 10 (Fig. 4).

Clutch sizes from the literature or museum co lections (24 nests) varied from four eggs (16 pe cent of nests) to seven eggs (8 percent) with si egg clutches (42 percent) and five-egg clutches (3 percent) being most common.

Fall Migration

We do not know how early the southward fligh begin, but we detected notable population chang in central Illinois by the end of July (Fig. 4 Northern Illinois departure dates have ranged different places and different years from mid-Augu to November 7 (Clark & Nice 1950, and Ford 1956 Along the major rivers in western Illinois, lar aggregations of tree swallows may be expected fr late July to at least mid-October (Fig. 4). Da counts of several thousand birds are not unusu along the Mississippi River, and in the St. Lo area Anderson & Bauer (1968) have recorded t of thousands per day (see also Jones 1933). the same area Wilhelm (1954) reported 300 as l as November 1.

We have found much smaller numbers of grant tree swallows in the Rock River Valley th in the Mississippi and Illinois valleys. On the east side of Illinois, even in the Ohio Valley, no one reported numbers of tree swallows comparable those seen in the west (Fig. 4). However, relati little study has been given to the Wabash and O valleys, and higher populations than are prese known may ultimately be found there. Hess (19 spoke of seeing "armies" of tree swallows in c central Illinois in September, but there is no to interpret his statement in numerical terms. contrast to eastern Illinois generally, northeas Illinois may have large numbers of tree swall Nolan (1955) recorded a peak population of 2 birds at Fox Lake on October 1, 1954.

We saw many more tree swallows in the (August–October inclusive) than in the sp (March–May inclusive). The ratio was 1 bir the spring to 62 in the fall in the north (1968 to 18 in central Illinois (1969), and 1 to southern Illinois (1967 and 1970). It is our pression that in the fall swallows tend to sta the same areas for extended periods so that same birds are counted over and over a whereas in the spring they move through the more quickly. This behavior would have a bearing on the spring-fall ratio, but we still be that the fall population greatly outnumbers spring population.

Winter Records

The regular winter range of the tree sw lies no closer to Illinois than a few hundred to the south and east (Fig. 3), and the al record of a flock of 200 near Springfield on D

17, 1939 (Anon. 1940) must be considered in-
d in the absence of supporting evidence. There
no valid winter records for Illinois.

d Habits

There have been no studies on the food of the
swallow in Illinois, but we have often observed
the large migrant swarms of this and other
llow species occur coincidentally with extensive
rms of midges (Chironomidae). When feeding,
birds will even flutter against trees and shrub-
to put the small flies into the air, though most
he insects are taken in regular flight. We believe
chironomids form an important part of the diet of migrant swallows, but detailed quantitative studies are very much needed.

BANK SWALLOW *(Riparia riparia)*

(Fig. 6 and 7)

Spring Migration

So far as is known the migration of the bank swallow is diurnal, and the actual flights have been reported only near large streams or rivers (Cooke & Widmann 1884, and Barnes 1933).

The earliest spring arrivals have been seen April

Fig. 6.—Bank swallows. The dark chest band is the distinctive mark of this brownish-backed species.

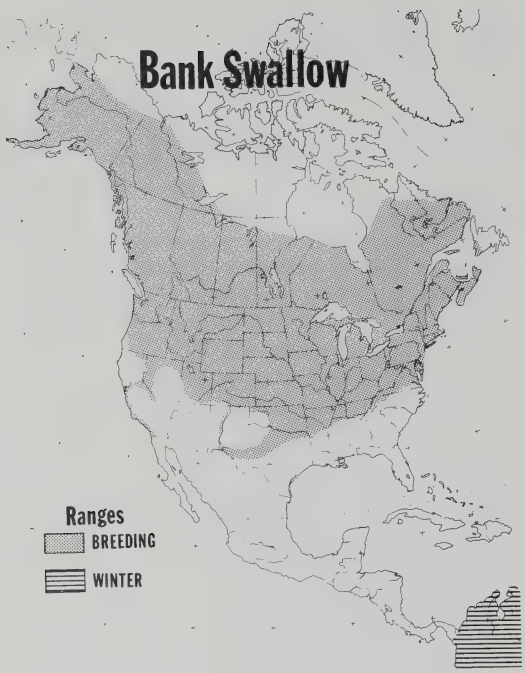


Fig. 7.—General North American distribution of the bank swallow. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and paucity of suitable habitat. The breeding population is particularly spotty in the South. The bank swallow winters widely in South America and also has a wide distribution in the Old World where it is known under the common name of sand martin.

3 and 4 in southern and central Illinois, and April 11 in the north, but bank swallows do not usually arrive in numbers until after April 20, and the heaviest influxes occur around mid-May (Fig. 8). In the spring we saw the largest numbers in northwestern Illinois in 1968, but we do not know whether this represents regional or annual variation in the population.

Distribution

The North American distribution of the bank swallow is shown in Fig. 7. The Illinois distribution (Fig. 9) is far from adequately known, and the large areas with no nesting records in eastern and southern Illinois probably contain many bank swallow colonies that have not been recorded as yet. Blocher (1922) observed that bank swallows could be found almost anywhere along the Green River, and colonies are probably present along large stretches of all the major rivers (at least the Mississippi, Rock, Illinois, Wabash, and Ohio), but there are no data on the numbers and spacing colonies along any stream in the state.

Nesting Habitats and Populations

No one has attempted a precise definition bank swallow habitat. Musselman (1921) indicat that the species occurred where clay banks a water were in proximity. Nesting colonies ha been recorded in loess, till, clay, sandy, and bla soil banks (Schantz 1923, Strong 1898, Sillow 1906, Ridgway 1887, and Hess 1910) as well as natural cavities in rock cliffs, and in sawdust mou (Fig. 10 and 11). Hess (1910) felt that bank sw lows preferred black soil to sandy soil in east-cent Illinois, but there have been no systematic stud of soil usage by either of the burrowing swallo (bank and rough-winged). Nesting banks h varied in height from 5 to 75 feet.

Nearly all of our observations on foraging b swallows involve either water areas or grassla especially pastures (Graber & Graber 1963). T bank swallow is a colonial nesting species, and th are no population estimates that take forag habitat into account. Beecher (1942) found pairs in 1.27 acres, and 20 pairs in 0.25 acre, banks in Lake County. Gault (unpublished no 1912) found a colony with only 2 pairs, but gro of 20 to 200 pairs are more typical. The lar colony, with 6,000 burrows, located on a cliff Rock Island, was reported by Fawks (1938), by 1966 it was down to 250 pairs (Fawks 19 Bank swallow colonies are at the mercy of who excavate the banks, and of those natural fo that either erode away the banks or cover t with vegetation. However, the same eroding or cavating processes that destroy nest banks also cr them (Ford 1915). At present there are no from which to judge whether banks are being troyed faster than they are being created. A colonies have survived many years. The colon Rock Island, for example, is probably at leas years old.

Nesting Cycle

Information on the nesting cycle of bank lows in Illinois is meager. In northern Illinoi first noticed these swallows working on their bu on April 22, and carrying nesting material on 29, but some groups of birds did not even a at their nesting banks until May 10. Further s in Macoupin County, Silloway (1906) saw bu being dug on April 25, and in the St. Louis, Miss area Widmann (1907) noted that most pairs not begin nest building before May 5. Bu depths recorded in the north by Petersen (per communication), A. C. Murchison, Loucks, Barnes (unpublished notes) varied from 18 i

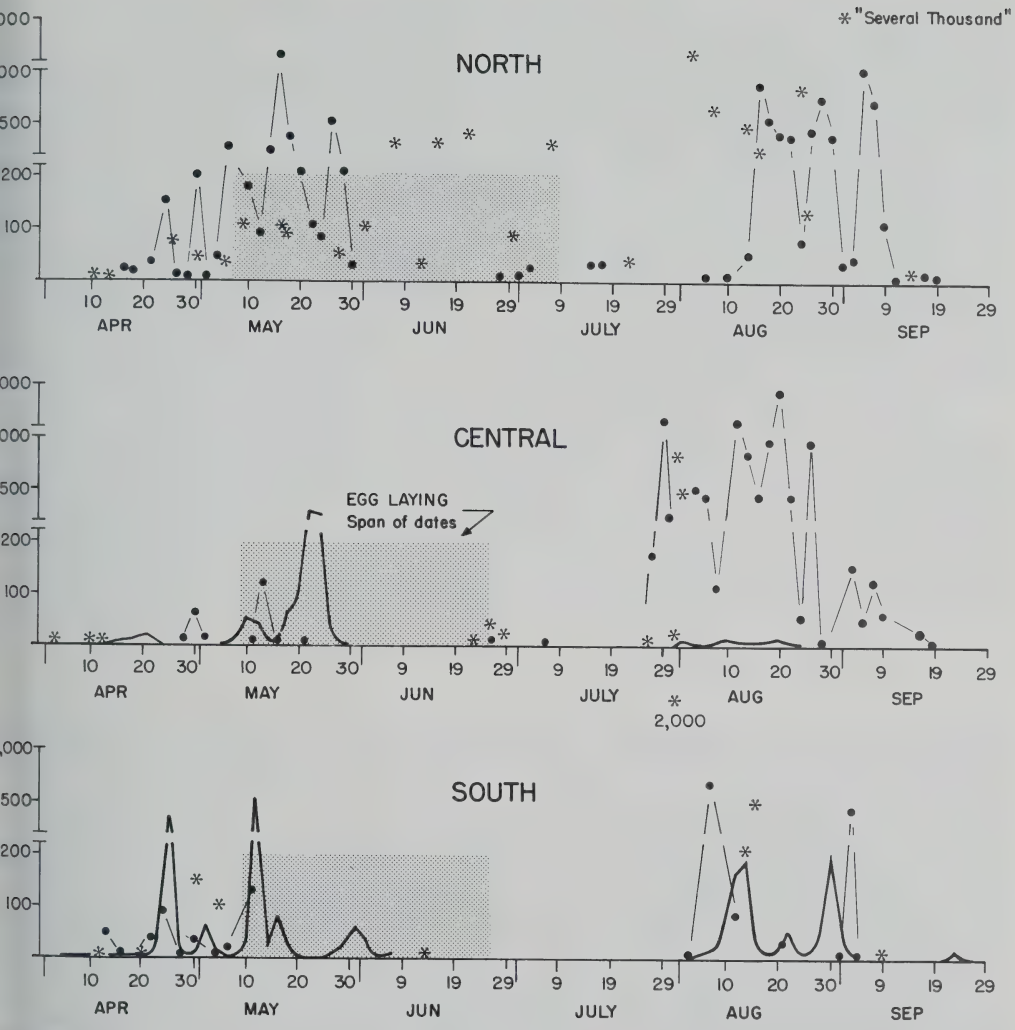


Fig. 8.—Egg-laying and migration seasons of the bank swallow in different areas of the state (see Fig. 1). Spring and fall graph (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other years other observers. Shaded areas show the span of dates during which egg laying has been recorded. Dot symbols represent counts on the western side of the state; lines without dots represent the eastern side.

feet, with 2–3 feet being most common. Near Louis, Missouri, Philo W. Smith (unpublished s) recorded a burrow 6 feet in depth.

We have insufficient data to construct a quantive curve of the egg laying season, but laying rs from at least May 7 to July 9 in the north . 8). Much less complete information for cen- and southern Illinois (combined) indicates a laying season from at least May 9 to June 26. At a Tazewell County colony we observed many young just ready to fledge on July 31, and John Schwegman (personal communication) saw bank swallows still entering their burrows, possibly feeding young, on August 14 in extreme southern Illinois. There are no published estimates of nesting success or productivity.

Fig. 9.—Breeding records for the bank swallow in Illinois.

Fall Migration

We cannot say when the fall migration actual begins, but by July 15 we have seen groups of ba swallows arriving in areas where there are no c onies. After mid-July it becomes increasingly co mon to see flocks of bank swallows, sometim numbering hundreds of birds, closely spaced alo the power lines. It is a scene especially typical the large river bottoms of western Illinois; by co parison, very small numbers are seen in east-cent Illinois (Fig. 8). In August we often witnessed t strong affinity for heat which bank swallows a some other species of swallows show. In the hott part of the day the birds would rest on the grou and press themselves against hot sand in the ro

During July and August bank swallows parently roosted regularly in the large commu roosts of purple martins along the Mississippi Ri near St. Louis (Widmann 1898).

Peak populations came in August and early S tember, and bank swallows were virtually gone mid-September. Our last record was September in southern Illinois. Strode (1892) reported a g migration of thousands of bank swallows along Spoon River on September 25, 1891. This servation may have been based on a misidentificat of tree swallows, but in view of the bank swall

Fig. 10.—Site of nesting colony of bank swallows in a sawdust mound. Note the burrow entrances in the bank wall (near ce

Fig. 11.—Close-up of one burrow entrance in Fig. 10, showing young bird about ready to fledge.

rmous range in the north, the record cannot liscounted.

For the state as a whole, we saw about three k swallows in the fall for every one seen in the ng, but in eastern Illinois the ratio was exactly rsed, three in the spring to one in the fall. k swallows are apparently more widely dispersed he spring than in the fall, i.e., they are more entrated on the western rivers in the fall.

There is one published banding record which cates the winter destination of Illinois breeding s. A bank swallow banded at Palos Park, July 1939, was recovered January 6, 1940, about 0 miles SSE, at Iquitos, Peru (Cooke 1950).

UGH-WINGED SWALLOW

(Stelgidopteryx ruficollis)

(Fig. 12 and 13)

ng Migration

The actual migration flights have apparently not n witnessed in Illinois in the spring, but they presumed to be diurnal, as in the fall (see below). gh-wings generally reach Illinois a week or two er than bank swallows (Fig. 8 and 14). Widmann (1907) noted the arrival of rough-wings at St. Louis as early as the second week in March, but we did not record the species in extreme southern Illinois until March 30, and they did not appear in numbers until April 13 (Fig. 14). We have no March records for central or northern Illinois, and the earliest published records are April 6 and 9 (Silloway 1922, and Boulton & Pitelka 1939). Rough-wings are generally seen only in small numbers until after April 14 (it is unlikely for an observer to see more than 10 per day), and peak spring populations occur between April 20 and May 20 (Fig. 14). Rough-wings are much less gregarious than bank swallows, and appear to be less common (Fig. 8 and 14). Counts of rough-winged swallows were generally higher in western than in eastern Illinois, and the central Illinois counts were inexplicably lower than counts in either southern or northern Illinois (Fig. 14).

Distribution

The general distribution of the rough-winged swallow is shown in Fig. 13, and the Illinois breeding range, so far as it has been recorded, is shown in Fig. 15. Illinois records are undoubtedly very incomplete. Rough-wing colonies are often located in the same banks where bank swallows nest, expecially along major streams.

Fig. 12.—Rough-winged swallows in fresh plumage in early August. (The brown back and brownish gray wash on throat breast are marks of this species.)

Nesting

Rough-winged swallows are not nearly as strongly colonial as bank swallows. Hess (1909) seldom found colonies of more than five or six pairs, one or two pairs at a place being much more common, in east-central Illinois.

Rough-wings apparently nest in a greater va of situations than do bank swallows. In additio nesting in the banks of larger streams, rough-w nest in the lower banks of small streams, in cre in cliffs and even of buildings, in drain tiles, ar holes in bridges (Beecher 1942, Bodensten Mooney 1925, Moyer 1924, and Ridgway 1

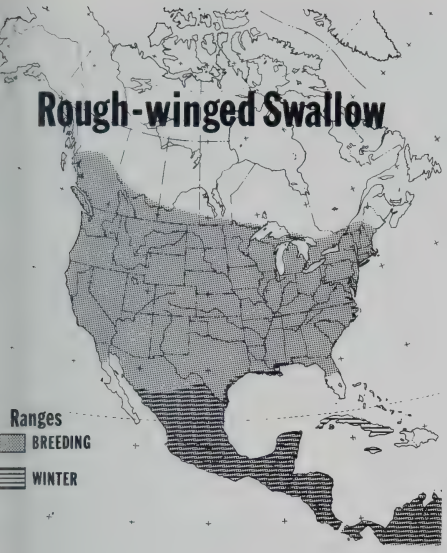


Fig. 13.—General North American distribution of the rough-winged swallow. The outlined range may include large sections in which populations of the species are thin or even absent, because of the nature of the terrain and paucity of suitable habitat. The species also breeds widely in South America. The break in the range at Panama marks the suspected southern limit of winter range of North American populations.

Hess (1910) found that rough-wing burrows were not generally as deep as those of the bank swallow. Only a few rough-wing burrows have been measured, nearly all in nothern Illinois. They varied in depth from 10 inches to 3 feet, 18–20 inches being most common.

A photograph of a nest with eggs, removed from the burrow, was published by Hess (1909). Four nests were described as being made of dry grass, corn leaves and husks, and weed stems and rootlets (Loucks, unpublished notes 1891, Blocher 1922, and Goelitz 1915).

The nesting cycle of this species has received almost no attention in Illinois. Egg laying spans from at least May 7 to June 14 in northern Illinois (Fig. 14). Clutch sizes in 14 nests varied from

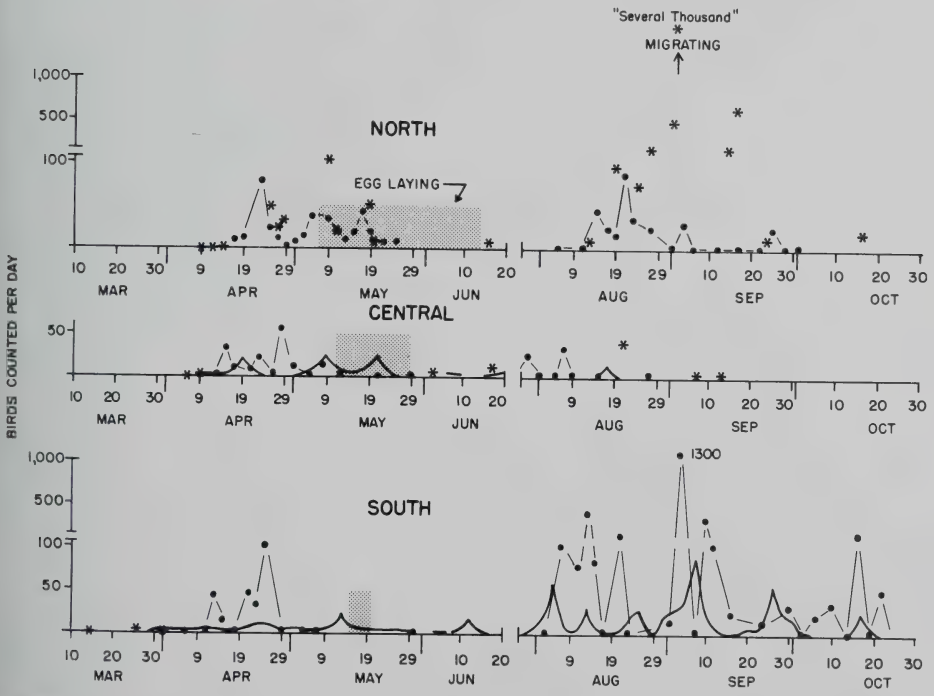


Fig. 14.—Egg-laying and migration seasons of the rough-winged swallow in different areas of the state (see Fig. 1). Spring and graph lines (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in er years or by other observers. Shaded areas show the span of dates during which egg laying has been recorded. Dot symbols resent counts made on the western side of the state; lines without dots represent the eastern side. Arrow symbol indicates date actual migration.

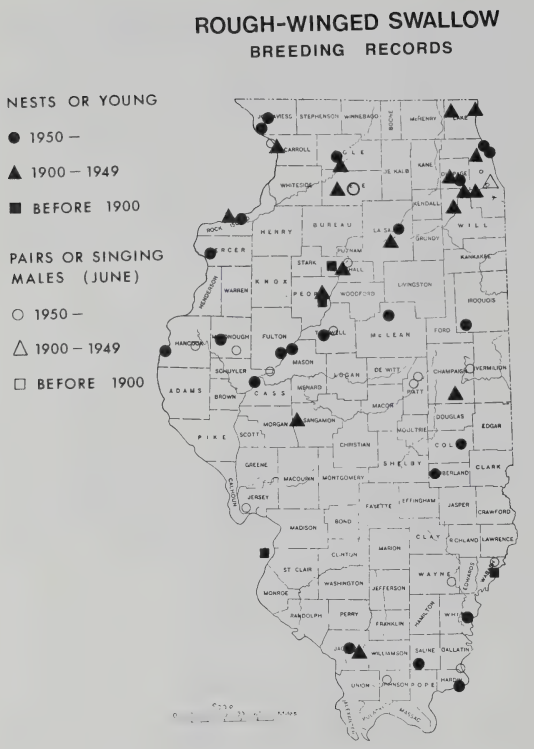


Fig. 15.—Breeding records for the rough-winged swallow in Illinois.

four to eight eggs. The eggs are white. There are no data on nesting success or productivity.

Fall Migration

Some kind of movement, perhaps local, of rough-winged swallows begins in northern Illinois at least as early as July 23, when we have seen the birds in "new" areas away from nesting sites. In southern Illinois in early August, small groups (3–20 birds) appear widely, away from nesting sites. In mid-August and late August, many rough-wings are molting heavily, including their flight feathers.

The only observation known to us of an actual migration flight is that of Mr. and Mrs. Harry A. Shaw (personal communication) of Sterling, Illinois, who saw a fairly steady flight, involving several thousand rough-wings and some nighthawks, passing over Sterling between 2:00 PM and dark on September 2, 1968 (Fig. 14). The birds were moving south or slightly east of south. This impressive migration coincides with the time of other pe counts of rough-wings in Illinois (Fig. 14), and su migrations should be looked for each year throug out the state. They may be of regular occurren

As in the spring, our poorest counts were central Illinois. Our highest counts were in the sou on the western side of the state (Fig. 14). As wi other species of swallows, the largest aggregatio of rough-wings were seen near the large rive For the state as a whole, we saw about 4 roug wings in the fall for every 1 seen in the spring, b the ratio in the south was nearly 11 in the fall 1 in the spring. In central Illinois the ratio reversed with only 1 bird seen in the fall to 6 in spring.

BARN SWALLOW *(Hirundo rustica)*

(Fig. 16 and 17)

Barn swallows begin to appear in Illinois March (only slightly behind the tree swallows), least as early as the 18th (Silloway 1906). first conspicuous waves of barn swallows have b observed on April 3 in southern Illinois, April in central Illinois, and April 25 in the north (18). Peak spring populations were present f April 11 to May 17 in the south, April 25 to Ma in central Illinois, and May 9 to 30 in north Illinois (Fig. 18). There was a tendency for sp waves to come earlier to western Illinois, and l to the eastern side of the state (Fig. 18).

Local populations appear to be fairly consis in the timing of their spring arrival. One l County barn colony usually appeared between A 11 and 13. A 25-year record of arrivals near Lib Illinois, showed the first barn swallows coming tween April 1 and April 22, but most consiste between April 13 and 17 (Loraine Funk, pers communication).

Though we believe the migration to be diu there are, surprisingly, no published descriptio the actual spring migration in Illinois, and we observed the actual migration flight only in the

Distribution

The North American distribution of the swallow is shown in Fig. 17. The species also a broad distribution in the Old World. The swallow is another species that probably nes nearly every township in Illinois, but, as yet state distribution is incompletely recorded (Fig.

Nesting Habitats and Populations

Barn swallow nests have been recorded in types of situations in Illinois: (1) barns,

Fig. 16.—Barn swallows (about one-half life size) attending a young bird which fledged prematurely. The long white-marked r tail feathers are a distinctive mark of the species. (The back is glossy dark blue, and the underparts, chestnut-rufous.)

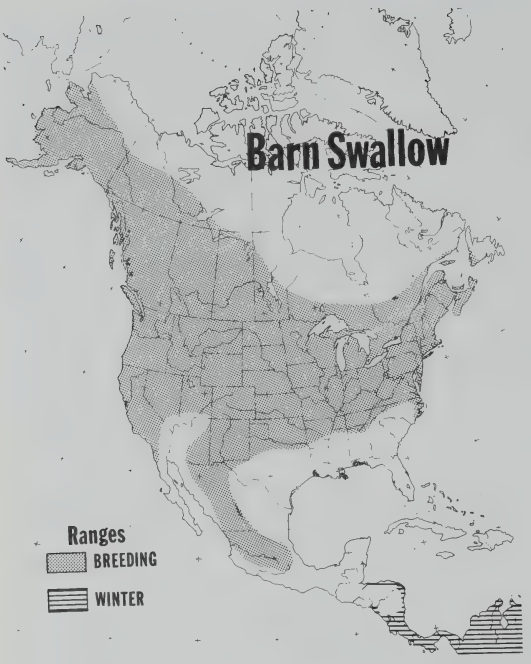


Fig. 17.—General North American distribution of the barn swallow. The outlined range may include large sections in which populations of the species are thin or even absent because of the terrain and paucity of suitable habitat. The barn swallow winters widely in South America, and also breeds in the Old World.

porches, houses, and other buildings, and (2) under cement or metal bridges and culverts. There are no quantitative estimates on the relative use of the two settings for any area of the state. One barn in Johnson County had 41 swallow nests (Petersen 1970), and we have seen bridges in the south with 20 or more nests.

The statewide censuses of 1957–1958 (Graber & Graber 1963) showed barn swallows foraging over a great variety of open field habitats, but favoring edge shrub areas (26 birds per 100 acres), alfalfa (13 per 100 acres), sweet clover (12 per 100 acres), pastures (10 per 100 acres), and ungrazed grasslands (7 per 100 acres). Guth (1965, 1966, 1967) conducted breeding bird censuses of an alfalfa-clover field in Tazewell County, and found densities of foraging barn swallows in different years of 4, 7, and 12 birds per 100 acres. Robertson (1941, 1942, 1944) found foraging densities of barn swallows over swampy prairie in Sangamon County to be about 3, 7, and 9 birds per 100 acres in different years.

The barn swallow has undergone striking population changes through the years in Illinois. Ear in this century the species was most abundant in th northern part of the state (Graber & Graber 1963 Ridgway (1915, and in Gault 1922) reported th in southern Illinois the barn swallow (as well the cliff swallow) had almost entirely disappeared a breeding bird. This scarcity was also shown the censuses of 1907–1909, when the June popul tion for the whole southern third of the state d not exceed 20,000 birds. For the same area 1957, we estimated the population to be abo 500,000 birds, and it was even higher in 1958. T population also increased in central Illinois, fr about 100,000 in 1907–1909 to 300,000 in 195 1958, but the northern Illinois numbers did change (about 150,000 in 1909 and in 1957–195

The remarkable recovery of the barn swallow southern Illinois was not duplicated by the c swallow, and its populations remain very low in south. Ridgway (1915) attributed the early 1 century decline of both species to interference fr a growing house sparrow population in Illin How and why the barn swallow overcame this pr lem when the cliff swallow could not is a myst though one factor may be the cliff swallow's cove nest structure which is probably more attractive house sparrows than are the open nests of b swallows. There is an indication that house spar populations in rural habitats declined in south Illinois after 1900, following the human popula to urban areas (Graber & Graber 1963). This wo have helped to remove competition pressure f the barn swallow. It is also possible that swallows made increased use of cement bridges culverts for nesting. Futhermore, we have n that isolated or recently abandoned farms in soutl Illinois have nesting barn swallows, but no, or sparrows. Though we have found sparrows u barn swallow nests at colonies in all regions of nois, there is no recent evidence that sparrows tually displace barn swallows from active nests.

Nesting Cycle

Merrill (1947) recorded the same barn swa nest being used 7 consecutive years (with an remodeling) in Fayette County, but only Mussel (1939) has reported homing returns in Illinoi the basis of a banded bird, a female whic turned "several years" to a barn in the Quincy

Nesting activities may begin very soon after swallows arrive in the spring, as we have rec egg laying as early as April 15 in southern Ill and April 23 in central Illinois, but not before 6 in the north (Fig. 18). Most of the egg duction comes between early May and mid and the egg-laying curve has several peaks (Fig. This suggests that two or more broods are r but though barn swallows have been reporte

se two or three broods, this premise has not been stantiated from observations of banded birds in nois. Re-use of a successful nest is not proof of ible-broodedness.

Surprisingly, for such an interesting nest struc- e, there are no published notes on the nest build- phase of the cycle for the barn swallow. Loucks npublished notes, 1890) stated that the nest was de of mud and hay, loosely lined with white thers. Studies of nest construction in relation to types would be of interest. Are barn swallow pulations reduced in sandy soil areas?

For four June nests in southern and northern nois, we recorded nest-building periods of 8, 9, and 12 days. Incubation periods for several ts in central and southern Illinois varied from to 16 days, most frequently being 15, and nes- g life was 16–20 days. Davis (1968) also recorded estling period of 16 days. Thus, one nesting cycle, luding egg-laying for a four-egg clutch, would uire 41–51 days, which is about the interval be- en the May and July peaks in egg-laying (Fig. , and further indication of double broods.

Most barn swallow nests receive five eggs. Many eive four, and six-egg clutches are not uncommon able 1). There is at least one record of a nest h seven eggs (Blocher 1926). Clutch size declines htly as the season passes (Table 1). The disparity the number of five-egg clutches in April and y between central and southern Illinois (Table 1) puzzling, but sample sizes are small and more data needed to determine if the differences are real.

Nesting success (Table 2) was similar for our nples of barn swallow nests in central and south- Illinois (65–70 percent of eggs produced fledge- gs), but the sample for northwestern Illinois wed very low success (only 21 percent). Larger nples of nests and more years of study are needed show whether there is truly such marked regional iation in nesting success of barn swallows. We not account for the poor success observed in the thwest on any quantitative basis, because of the ll sample. We saw one active barn swallow t usurped by house wrens, as did Schafer (1916) in the same region. House sparrows occupied ew inactive swallow nests in all regions. More ts fell and more eggs disappeared in the north-

Table 2.—Fledging success of barn swallows.

Region	Year	Number of Nests	Percent Fledged	
			Nests	Eggs
Northwest	1968	17	26	21
Central	1969	47	74	70
South	1967	51	70	65

west than in the other regions. No other causes of nest failure have been recorded. The question of early-season versus late-season nesting success also needs quantitative study.

Davis (1968) has provided the only Illinois data on the care and feeding of young barn swallows in the nest. He observed that the adult birds made between 12 and 31 feeding trips per one-half hour, and he estimated that the adults made 626 trips per day to feed a brood of five 10-day-old nestlings. He captured the adults and observed that the food they were carrying was flies (species not reported), a minimum of five per trip.

Fall Migration

Some barn swallows remain near their nesting areas (barns, bridges, etc.) weeks after the last young have fledged, but generally the departures of swallows from local colonies can be detected during late July and August, even though the birds may not leave all at once. We have seen active migration as early as July 23 in northern Illinois, and migration flights have been observed widely in August. Our observations are much like those of Barnes (1933) who described the migration as a continuous passage of birds southward, singly, in pairs, and in small groups. We have also seen more concentrated migrations, involving hundreds of birds passing in a few minutes, particularly along the Mississippi valley in August. Such migrations often involve more than one species of swallow. In contrast to the circling foraging flights, the migration flights are straight, and the flight directions we have recorded were south (mainly) and southwest. All of the flights we have observed were probably within 250 feet of the ground, but flights at higher altitudes could easily be overlooked. There are no data on the timing of the flights through the day, and we do not

Table 1.—Clutch sizes of barn swallows in Illinois.

ion	Months	Number of Nests	Average Clutch	Percent of Nests by Clutch Size			
				6 Eggs	5 Eggs	4 Eggs	3 Eggs
th	June–July	22	4.5	14	41	27	18
tral	April–May	21	4.9	10	71	19	0
	June–July	32	4.6	9	50	31	9
h	April–May	26	4.8	27	42	27	4
	June–July	30	4.3	0	43	43	13

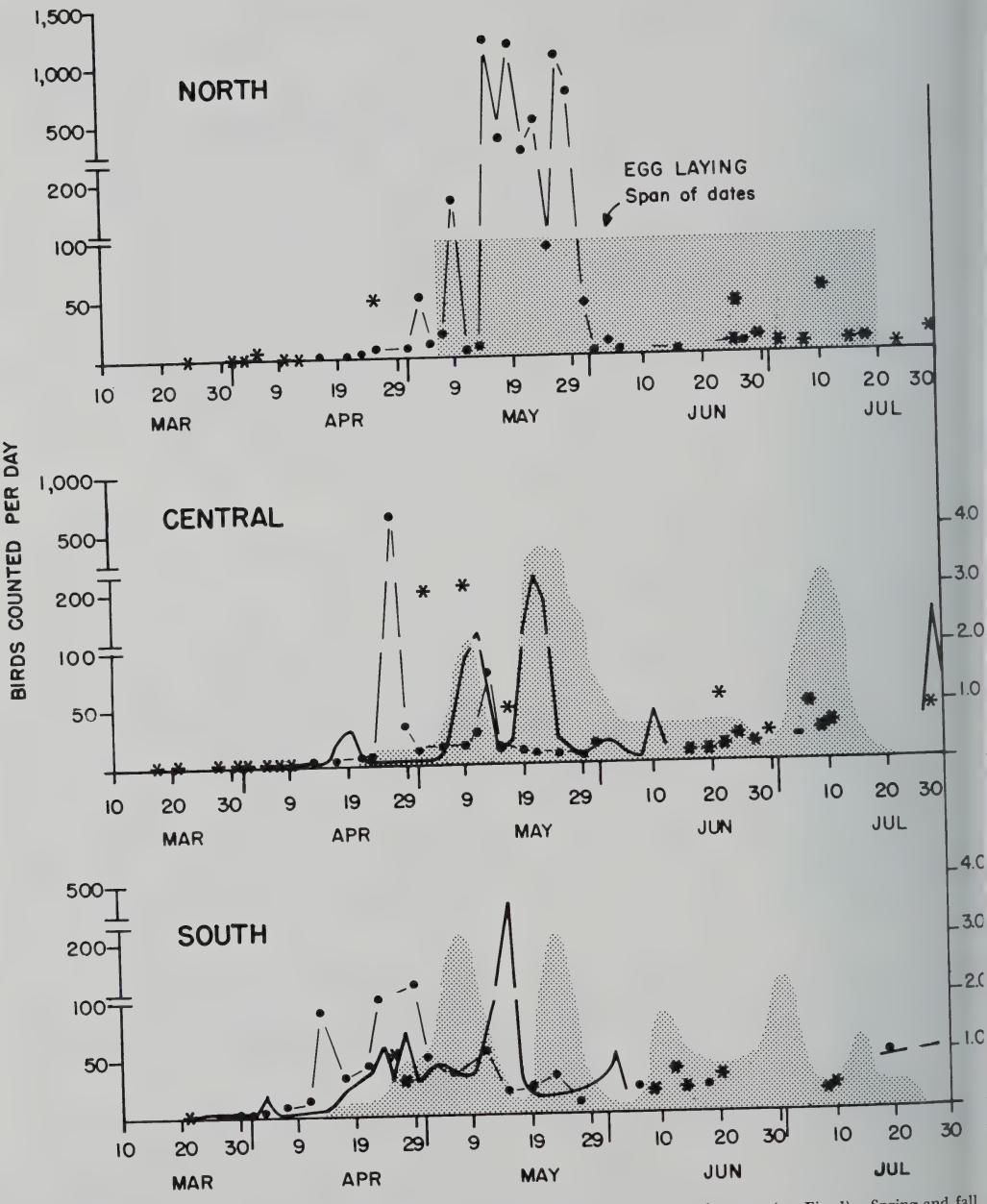
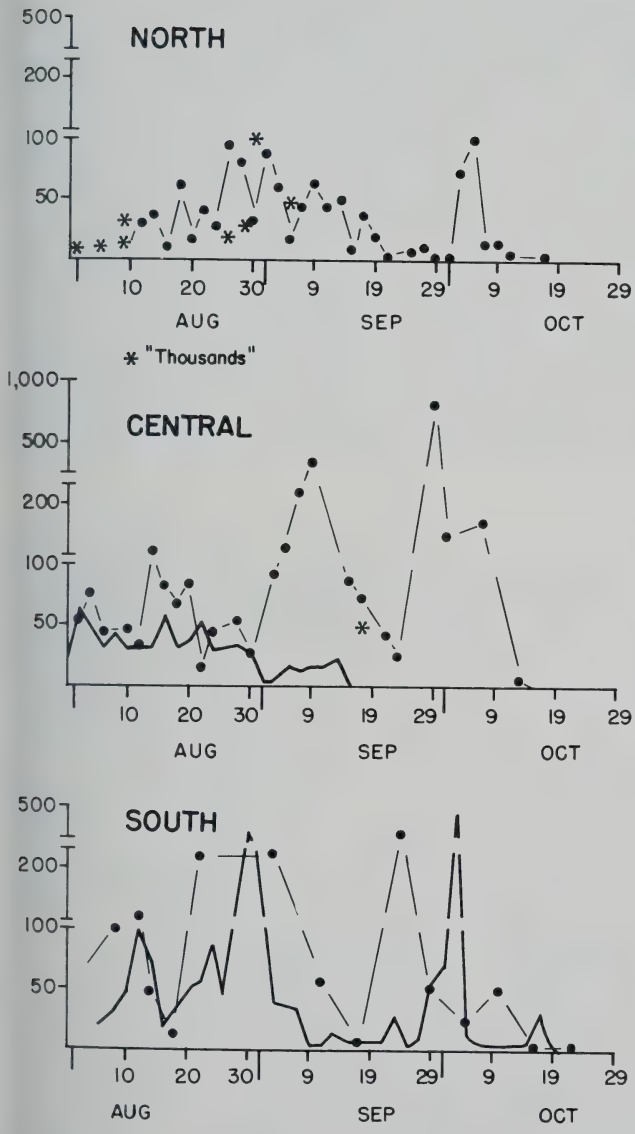


Fig. 18.—Egg-laying and migration seasons of the barn swallow in different areas of the state (see Fig. 1). Spring and fall lines (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other or by other observers. Shaded areas show the percent of eggs laid on a given date (right scale) or the span of dates during egg laying has been recorded. Dot symbols represent counts made on the western side of the state; lines without dots represe eastern side.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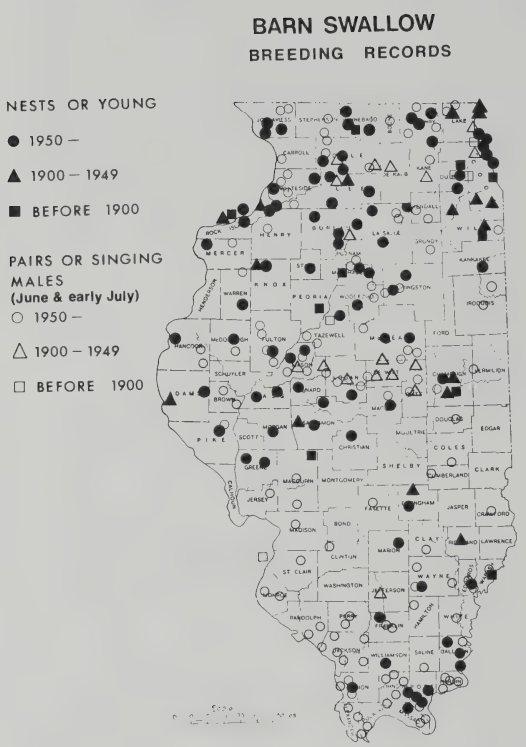

Fig. 19.—Breeding records for the barn swallow in Illinois.

know whether the flights are restricted to narrow corridors, such as river valleys, or occur on broad fronts. A very spectacular flight of barn swallows and other species, perhaps numbering tens of thousands of birds, was witnessed by Loraine Funk (personal communication) on August 10, 1971, near Lake Meredosia. The birds were moving ahead of a storm, which may have concentrated birds from a large area.

Many observers record the last barn swallows of the year in August or September (Oberholser 1918, Clark & Nice 1950, and others), but large numbers of barn swallows may be seen in Illinois well into October (Fig. 18), especially along major water courses, and in 1971 a few were detected as late as November 6 on the Chicago lake front. We recorded peak fall populations in the state between August 12 and October 9. In southern Illinois, Nelson (1877) noted that barn swallows became abundant toward the last of August, and our censuses also show this pattern (Fig. 18).

In central and southern Illinois we saw about two barn swallows during fall migration (mid-July to mid-October) to one in the spring (April and May), but in northern Illinois the massive migration of 1968 reversed the ratio, and we saw only on bird in the fall to four in the spring.

In Missouri, Widmann (1907) observed larg aggregations of barn swallows and other species marshes, where the birds roosted regularly in th fall. Large roosts of barn swallows have not bee reported in Illinois, though Nelson (1877) did no large groups of barn swallows, cliff swallows, ar martins appearing in the evenings in late Augu near Cairo. Presumably there was a roost in th area, but Nelson gave no description or locati of it. Especially in the Mississippi Valley, we ha observed hundreds of swallows resting on cornstal during the late evening and early morning. In li of marshes, the swallows were apparently using co fields as roosting areas.

Winter Records

There is one winter record for the barn sw low in Illinois, two birds observed closely and peatedly at the Carbondale Reservoir during Christmas count on December 29, 1954 (An 1955). There is no other evidence that the bi actually wintered through in Illinois, and the rec should be considered accidental.

Food Habits

Forbes' (1878) study included only two sp imens of barn swallows, and no significant data this species. The only other information on food in Illinois, aside from Davis' (1968) ob vations on the feeding of nestlings, as mentio above, is that of Chase (1896) who observed a b swallow regurgitate pellets which were compo almost entirely of the hard indigestible wing co of very small beetles. There is a great need thorough studies of the food habits of this and other species of swallows.

CLIFF SWALLOW *(Petrochelidon pyrrhonota)*

(Fig. 20, 21, 22, and 23)

Spring Migration

A few cliff swallows reach Illinois as earl March 29 or the first of April some years, they are not usually seen until mid-April (Oberh 1917), and not generally in numbers until late A or May (Fig. 24). Cooke & Widmann (1884) fo that most of the local breeding population returned to the St. Louis area by May 3. T appears to be great annual variation in the sp populations. In 1968, migrant cliff swallow po tions were high. Censusing in northwestern Ill (Fig. 24), we had one count (May 19) of n 10,000 birds, and about the same time Frank Bel

Fig. 20.—Site of cliff swallow colony on the Apple River in Jo Daviess County. A cluster of (darkish) nests may be seen on the in the foreground, left of center.

Fig. 21.—Close-up of cliff swallow colony showing birds at their retort-shaped nests. One nest (center bottom, with bird facing) the shell only about half completed. Note pale rump of bird in flight; this is a field mark of the species.

Fig. 22.—Cliff swallow, about life size, ready to enter nest. Note the whitish forehead, a field mark for the species. When ony is disturbed, many birds remain in their nests, but peer out as the bird below is doing.

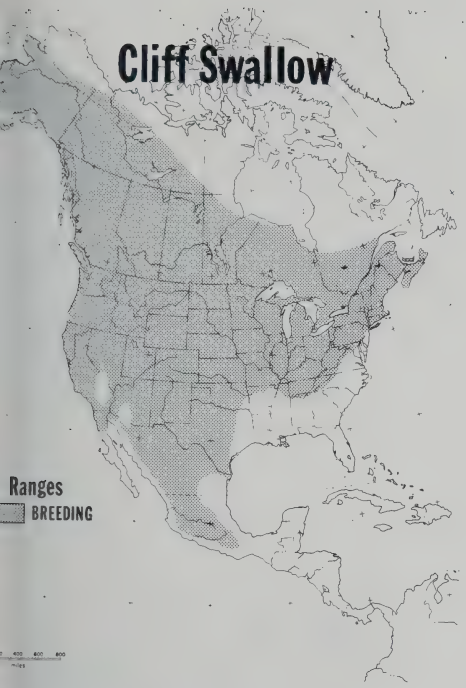

Fig. 23.—General breeding distribution of the cliff swallow. outlined range may include large sections in which pop- ons of the species are thin or even absent because of the re of the terrain and paucity of suitable habitat. Cliff ows winter mainly in the southern half of South America.

rsonal communication) found exceptional num- near Havana, in central Illinois (Fig. 24). Sim- y, Anderson (1963) found exceptionally high pop- ions, many thousands, in the St. Louis area during second week of May, 1963. Our counts for central southern Illinois in other years were much lower, the marked annual variation precludes any com- t on possible regional variation. The migration ls study over a long period of years.

Gault (unpublished notes, 1892) witnessed the al diurnal migration of cliff swallows near Glen n on May 15, when he saw flocks moving directly h. There is no other reference on, or description the actual migration flights.

ribution

The general distribution of cliff swallows is shown ig. 23, and the Illinois distribution, so far as it has n recorded, in Fig. 25. There are no recent nesting rds for central Illinois. It is our impression that range of the species in Illinois has been steadily ding to the north, leaving only relict populations few places, and most of the state population now is probably in northwestern Illinois. Jo Daviess County has long been a dependable haven for this species (Kennicott 1853–1854).

We hope that further exploration of stream cliffs and bridges will turn up additional colonies throughout the state. Besides the nest records plotted (Fig. 25), there are breeding records for Cook, Lake, Champaign, and Piatt counties by Goelitz (1917), Ogle County by Allen (1868), and Sangamon County by Eifert (1945), but definite localities were not specified. There are no Illinois references on cliff swallow distribution in relation to soil types, but Butler (1891) believed that the swallow was almost strictly an upland species in southern Indiana because of the need for clay soils without sand for nest construction (see also Buss 1942).

Nesting Habitats and Populations

The cliff swallow is generally a colonial nesting species, though nestings by solitary pairs also occur. We have found single active nests along stream cliffs that were at least several hundred yards from any colony. Schafer (1920) recorded solitary nests on barns, and, at the other extreme, 256 nests on a barn (1932). Most of the colonies recorded, however, numbered between 12 and 100 nests.

No one has attempted a precise definition of cliff swallow habitat for any season, and though there are descriptions of nest sites (see Fig. 21), almost nothing has been recorded on foraging habitats. Our few records for the nesting season showed cliff swallows foraging over grasslands, hayfields, small grain fields, and streams.

Natural nesting sites are cliffs, especially cliffs with overhangs, usually along streams. Colonies along the Apple and Fox rivers are typical. Most of the published nesting records, however, refer to barn colonies, i.e., nests placed under the eaves of barns (Hammond 1939), often well away from streams. The use of barns as nest sites probably goes back to the early history of white settlement. Most of the cliff swallow population at one time was in colonies of this type in Illinois, but such colonies have been declining for many years. We know of only one still extant, although there are probably still several left in the northwestern part of the state.

In general, the breeding population of cliff swallows in Illinois appears to be in decline. There was a particularly striking change in the nesting population between 1880 and 1910. Ridgway (1887, 1915) saw the status of the cliff swallow change in parts of southeastern Illinois from common to absent. Similarly, in east-central Illinois Hess (1910, 1921) found cliff swallows common in the 1880's, yet by 1909 he recorded the last known nesting for the area. The same pattern was observed by Barnes (1912) in Marshall County, and there are many references which show the fading population in the Chicago area (Lewy 1943;

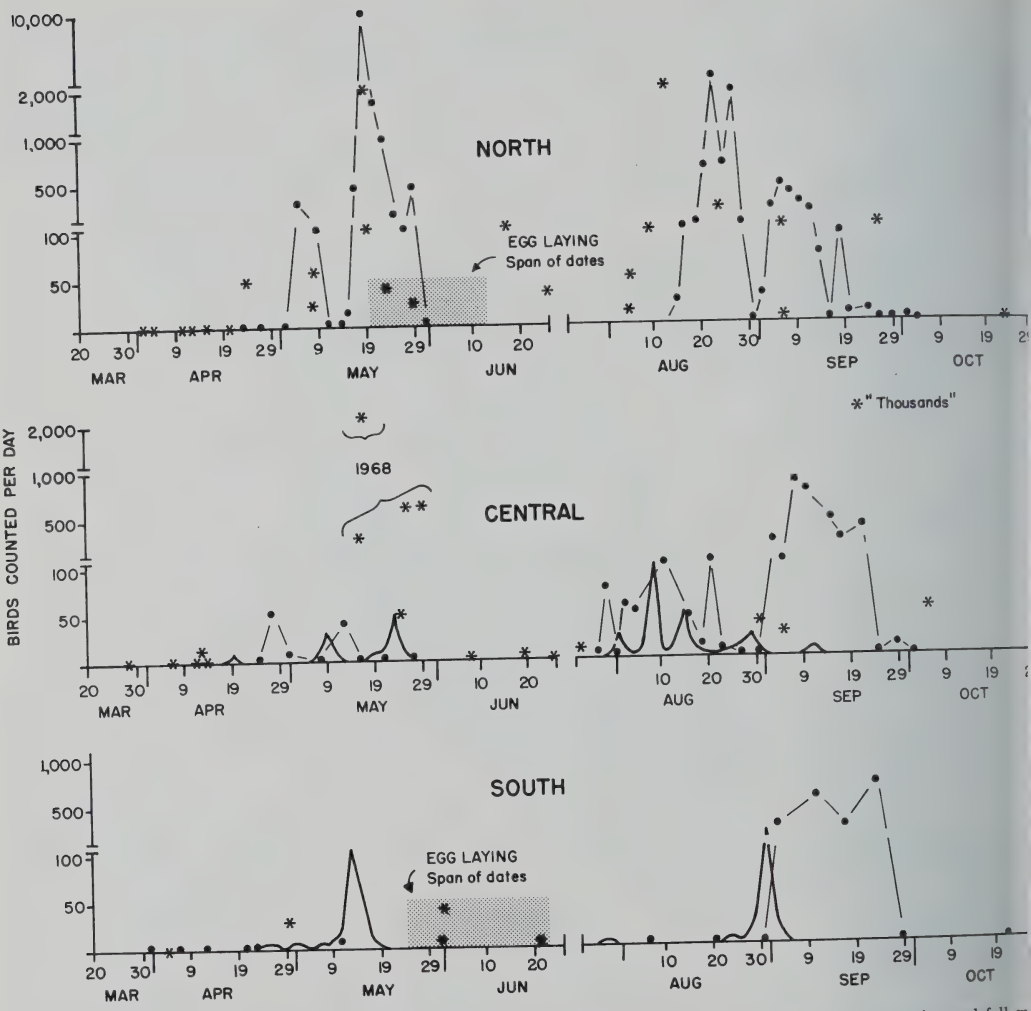

Fig. 24.—Egg-laying and migration seasons of the cliff swallow in different areas of the state (see Fig. 1). Spring and fall gr lines (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other y or by other observers. Shaded areas show the span of dates during which egg laying has been recorded. Dot symbols repre counts made on the western side of the state; lines without dots represent the eastern side.

Eifrig 1919; Ford, Sanborn, & Coursen 1934; Gault 1922; and others).

Most observers blamed house sparrows, which usurped swallow nests, for the decline, and the evidence is strong in support of this view. The house sparrow was then well on its way toward colonizing the state, and its population was expanding rapidly (Barrows 1889). The competition was observed directly. Loucks (1895), for example, saw a large colony of cliff swallows completely displaced by house sparrows. Schafer (1920, 1921, 1922, 1932) has provi the best quantitative history of a colony, and its p lems with house sparrows. Before the house sparr colonization of the state, the Schafer's barn in R Island County had about 200 cliff swallow nests e year. After house sparrows arrived, the cliff swa colony began to decline, and by 1913 the swal were gone. That year Schafer began a sparrow trol program. He protected the swallows and stroyed house sparrows. One pair of swallows retu

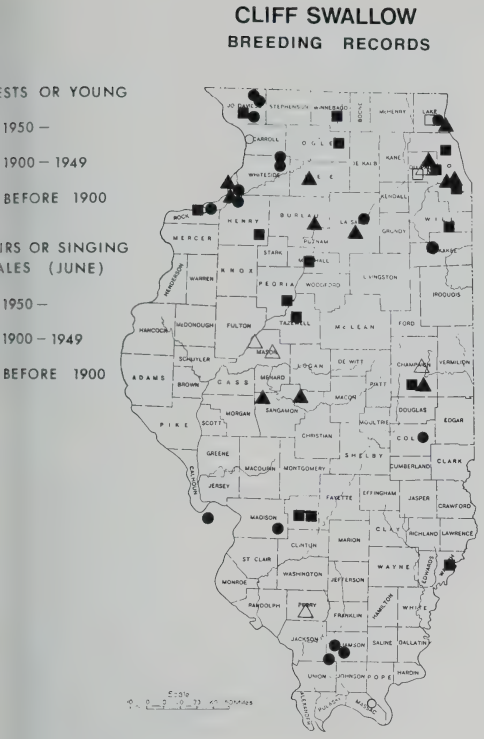

Fig. 25.—Breeding records for the cliff swallow in Illinois. record for Coles County represents attempted nesting by swallows in burrows at a bank swallow colony.

914, and by 1916 there were 3 pairs; by 1920 there e 65 pairs, and by 1932 there were 256 pairs. Cliff llows did not generally receive this kind of protec-n. Fawks (personal communication) recorded a n colony of 23 pairs of cliff swallows still in Rock nd County in 1958, but they had disappeared by l.

The problems of the cliff swallow with house spar-s continue. Every cliff swallow colony we have ted in recent years, including those in natural cliff s, has some sparrow occupancy of nests.

A worthwhile goal for bird students in Illinois uld be an annual census of the major nesting areas his species. Because most of the colonies are located ng a few streams, a virtually complete census of the e population could be made fairly easily each year, would clearly show the survival problems of the ies.

Despite the interest of many Illinois students in the swallow, there is almost nothing recorded on the ing cycle. Egg laying occurs from at least May 20 he north to June 23 in the south. More study will probably show that the egg-laying period extends much longer than this at both ends in both regions. There are no data for the central region. Schafer (1921, 1933) recorded that two broods were raised, and that one year all young were fledged by July 15.

There have been no measurements of nesting success or productivity, but a few causes of nest failure have been mentioned (other than the house sparrow, discussed above). Schafer (1923) recorded nest destruction by a red-headed woodpecker *(Melanerpes erythrouphalus).* Kimball (1889) recorded very high mortality of nesting birds in Winnebago County, apparently from starvation because of unseasonably cool weather that had reduced insect food in June right after nests had been completed. Kimball estimated that only 5 percent of the local population survived, and he examined many specimens found dead in nests and on the ground near nest sites. The specimens were extremely emaciated. Hammond (1939) reported on the loss of nests washed away by heavy rains, and Mrs. Albert J. Brown of Apple River told us of cliff swallow nests being washed away by flooding. Schafer (1932) recorded mortality of nestlings during exceptionally hot weather in June that seemed to cause birds to fledge prematurely. Dry weather also had an adverse effect sometimes, through its effect on the availability of mud for nest construction (Hammond 1939). Eifrig (1937) felt that the painting of barns had an adverse effect on cliff swallows, because nests did not stick well on painted barns.

Cowbird *(Molothrus ater)* parasitism of cliff swallows has been recorded in Illinois, but the incidence is negligible (Friedmann 1963).

The tick *Ixodes baergi,* which is parasitic on cliff swallows, especially nestlings, has been recorded in Illinois (Kohls & Ryckman 1962), but its influence, if any, on nesting success is unknown.

Fall Migration

Gault (unpublished notes, 1897, 1900) observed diurnal migration flights of cliff swallows on September 5 and September 16, but the southward flights must begin before September. In central Illinois we have seen groups of cliff swallows far from any nesting area as early as July 30, and in northern Illinois Mr. and Mrs. Harry Shaw saw the buildup of nonbreeding aggregations of cliff swallows from 50 birds on August 4, 1971, to about 2,000 by August 13. Our data for other years show a similar pattern in northern and central Illinois, but aggregations of migrant cliff swallows appeared later in southern Illinois (Fig. 24). At Cairo, Nelson (1877) noted that the species became abundant the last of August.

In August and early September nearly all of the cliff swallows we saw were in badly worn plumage, and in August we often saw them basking in roadways in direct sunlight, pressing themselves against the hot sand. We cannot explain this behavior, but other spe-

cies of swallows, most notably bank and barn swallows, did the same thing.

Observers generally give departure dates for the cliff swallow in mid-September or late September (Oberholser 1917, and Schafer 1917–1918), and our censuses also showed that most of the cliff swallow population is gone from Illinois by the end of September. A few birds have been recorded as late as October 22 in the south and October 24 in the north (Fig. 24; Clark & Nice 1950). Frank Bellrose (personal communication) observed an exceptionally late aggregation ("thousands") on October 16, 1970, flying south along the Illinois River Valley near Havana.

As with other swallows, cliff swallows were seen in greatest numbers near the large rivers, and on the western side of the state (Fig. 24). Cliff swallows were numerous along the Rock River, as well as the Mississippi, whereas tree swallows were found in much smaller numbers along the Rock River than the Mississippi.

Because of the exceptionally large spring migration in 1968, when we censused in northwestern Illinois, the spring-fall ratio of cliff swallows for the region (2 birds in the spring to 1 in the fall) differed greatly from the ratios in central (1 bird in the spring to 16 in the fall) and southern Illinois (1 in the spring to 7 in the fall). In most years, the fall population probably far exceeds the spring population throughout the state.

Food Habits

Forbes (1878, 1882) examined the stomachs of six cliff swallow specimens, one of which was collected in Tazewell County in the summer. He gave no locality or season for the other specimens. Beetles, including a scavenger beetle *(Aphodius inquinatus)*, were the dominant food items, with Hymenoptera (wasps and ants) next in abundance.

As in the case of other species of swallows, we have noted that the large aggregations of migrant cliff swallows coincide with conspicuous populations of midges (Chironomidae). In May, 1968, we observed cliff swallows feeding steadily on chironomids, notably *Chironomus crassicaudatus.*

PURPLE MARTIN *(Progne subis)*

(Fig. 26, 27, and 28)

Spring Migration

Cooke (1888) hinted that the purple martin's migration is nocturnal, but there is also some evidence of diurnal migration, as discussed below under Fall Migration. Martins have been observed to arrive at their nest sites at various times of the day, morning and afternoon (Gault, unpublished notes 1885–1905, Cooke 1888, and Cooke & Widmann 1884), and Widmann observed a few birds in what was apparently northward migration at 5:30 P.M. on March 30, 1885 (Cooke 1888). In view of the popularity of this species and its tendency toward gregariousness, it is surprising that no one has reported a large scale migration of martins in Illinois.

The earliest arrival date reported for the martin in Illinois was February 24, 1923, at Metropolis (Conley 1926), an exceptionally early arrival. Alleged martin records for February in Illinois often turn out to be based on misidentifications, but probably there are reliable (though rare) records in this month. March records prior to the 10th are probably unusual even in southern Illinois (Johnston & Hardy 1962), and though there are reports as early as March 5 for central Illinois (Nolan 1956), and March 10 for the north (Boulton & Pitelka 1937), the very first martins, usually adult males, are not likely to be detected before March 15 in the south, and March 23 in central and northern Illinois. Martins are subject to stress and mortality from cold (Jones 1910, Kimball 1889, Smith 1943, and Musselman 1966) though they have been known to survive 2 or 3 days of severe cold (15° F.) and snow (Nolan 1956, and Schafer 1921). Most of the state population does not appear until April or May. Yearlings arrive later, often weeks later, than adults (Cooke & Widmann 1884). The migration is prolonged, regularly extending from March into June, and our peak counts came between mid-April and the end of May (Fig. 29). The counts were lowest in southern Illinois and highest in the north.

Distribution

The general distribution of the purple martin is shown in Fig. 28. Though martins almost certainly nest in every township in the state, the Illinois nesting distribution (Fig. 30) has not been recorded in sufficient detail; there are no published records for whole counties of the state.

Illinois citizens are showing increasing interest in attracting martins, in part because of the publicity given the species by the Griggsville Wild Bird Society. Griggsville, Illinois is called the Purple Martin Capital, and is the site of an industry based on the birds (the manufacture of nest boxes and auxiliary equipment), and of a news publication, "The Purple Martin Capital News," an interesting source of information on martins and other birds.

Nesting Habitats and Populations

Even from early historical times purple martins have rarely been found nesting in natural cavities in Illinois (Ridgway 1874, and Ries & Werner 1946). A notable recent exception is the record of Peters (1966), who found martins nesting in tree stubs standing in the water of the Mississippi River near Thomson (Fawks 1966). There are no records of "[illegible]

ig. 26.—Adult male purple martin.

colonies in upland habitats, but this void may reflect the inadequate level of ornithological extion of Illinois. The percentage of the state lation nesting in natural cavities is unknown, but ably very small. Martins have also been recorded ng in the walls of buildings (Blocker 1933; ks, unpublished notes 1889), and in bridge supertures, besides bird houses of many designs (Anon.

side from recommendations on the placement of boxes—13–18 feet high, in the open (Widmann and Gault 1934–1935)—there are no data on the cteristics of even the domestic habitat of purple ns, though Widmann (1907) believed that old towns were most favored. There are, or have active colonies in the business districts of small e.g., Durand, LeRoy and Griggsville, Illinois, s near the Chicago loop as Lincoln Park, but the nce limits of martins to human traffic, as well eir essential habitat requirements, are unknown. than most Illinois species though, the martin seems safe from habitat destruction, what with the expanding acreage of human residential areas.

There are few population measurements for the purple martin in Illinois. Our strip censuses of urban areas in 1958 showed densities of 25 martins per 100 acres in northern Illinois towns, 11 per 100 acres in central Illinois, and 42 per 100 acres in southern Illinois. We recorded measurable populations of purple martins away from human residential habitat only in northern Illinois, where martins were foraging over fallow fields (about 4 birds per 100 acres), shrub areas (2 per 100 acres), oat fields (2 per 100 acres), soybean fields (1 per 100 acres), alfalfa fields (1 per 100 acres), and cornfields (0.2 per 100 acres).

In 1907–1909 Alfred Gross (personal communication) recorded June foraging densities for the martin in southern Illinois as follows: about 1 martin per 100 acres over fallow fields and pastures, 0.5 per 100 over cornfields, and 0.3 per 100 acres over hayfields. As all of these figures were based on cross-country censuses, the location of colonies in relation to available

Fig. 27.—Adult male and fem martins at nest box. The bird on t of the box is a first-year male.

habitats was unknown. The problem of foraging preferences of purple martins and other swallows could better be studied at individual colonies so that habitat use can be determined in relation to habitat availability. At present there are no such data available, and studies are needed.

Most significant and interesting are the studies of Karl Bartel (1945, 1946, 1955, 1959), who, with the help of Alfred H. Reuss, Jr. in the early years, censused the nesting martin population of Blue Island, Illinois, annually beginning in 1936. Blue Island, a city of about 22,000 people in northeastern Illinois, has an area of about 3.5 square miles (U.S. Bureau of the Census 1960). Between 1936 and 1959, Bartel (1959) recorded a low population of 151 pairs (about 13 birds per 100 acres) in 1937, and a high of 331 pairs (about 29 birds per 100 acres) in 1945 1950. On the average, the population varied c about 11 percent from one year to the next, but maximum variation was 29 percent between 1937 1938. Bartel also provided data on nest box util tion. Between 1936 and 1948, each year about 60 cent of the 53 available houses (yearly average) martins. Over a period of years about 92 percen the available houses were used by martins, based data from Bartel (1946). Of 10 houses that were 23 years, three had martins every year. At St. Lo Widmann (1922) had 86 percent occupancy of boxes by martins in 1888. Comparative data needed for other areas of the state.

The ups and downs of the Blue Island martin ulation could not be explained on the basis of

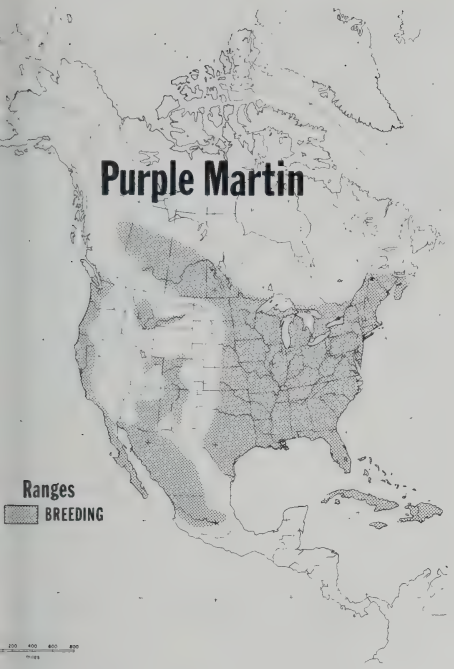

Fig. 28.—General breeding distribution of the purple mar- The outlined range may include large sections in which ılations of the species are thin or even absent because of nature of the terrain and paucity of suitable habitat. The er range of the purple martin is in South America, but ly known.

sical factor, or any single factor. One factor diffi- to evaluate was inconsistent care of nest boxes. factors most often mentioned in the literature ffecting martin populations are weather (Mussel- 1966, and Bartel 1947), and competition from se sparrows, starlings, and house wrens (Ridgway 5, Barnes 1890, Bartel 1946, and Widmann 1905). ig (1937) felt that martins declined with the de- e of horse stables, reflecting a reduced fly popula- . There are no precise quantitative data to show influence of any of these factors on martin popula- s. However, a crash in the martin population was erved widely in the Midwest in 1966, coinciden- with subfreezing spring temperatures after the tins had arrived, and dead martins were found nd around nest boxes (Petersen 1966, and Mussel- 1966). Martin populations were still somewhat ressed the following year in Illinois and Iowa tersen 1967).

ing Cycle

Though there are few published data on the nest- cycle for any Illinois population of purple martins, Widmann's (1884, 1922) studies of the species in the St. Louis, Missouri, area are important and pertinent. He estimated the time requirement for a successful nesting, to fledging, to be about 8 weeks—2 for nest building and egg laying, 2 for incubation, and 4 for the development of the nestlings. He believed that an additional 2 weeks of parental care were required after fledging. Widmann's figures are similar to those of Allen & Nice (1952) for a Michigan population, except that they recorded incubation periods of 15–19 days.

The early spring arrival of the purple martin in relation to its nesting has been a point of discussion by Widmann (1922), Johnston & Hardy (1962), and others. Though nest building has been recorded as early as March 24 in southern Illinois (Johnston & Hardy 1962), and April 18 in the north (Gault, unpublished notes 1906), the earliest egg date is "mid-April" in the south; it was May 5 in the north (Fig. 29), showing lapses of 2–3 weeks between nest building and egg laying. Widmann (1922), and Johnston & Hardy (1962), suggested that the early arrival and nest occupancy of the martin is related to intraspecific competition for cavities, going back to the times when only natural cavities were available, and probably in short supply.

Nest building, which is carried out by the female, is prolonged, interrupted sometimes for days at a time, particularly during inclement weather (Widmann 1922, and Johnston & Hardy 1962).

A variety of materials have been used for nest construction—paper, dry leaves, twigs, catalpa pods, asparagus stalks, dry grass, rags, string, straw, weed stalks, cow manure, and mud, the mud being used to form a solid wall or mat that slopes down from the box entrance to the rear of the box (Widmann 1880, Gault 1934–1935, Johnston & Hardy 1962, Loucks, unpublished notes 1889, and Silloway, unpublished notes 1920–1924). These students, as well as Barker (1965), observed that martins also often bring fresh green leaves to their nests. This behavior seems to be something more than just nest construction, as the leaves are brought after the nest is largely complete and from time to time through the nesting cycle. Leaves of pear (*Pyrus* sp.), poplar (*Populus* sp.), elm (*Ulmus* sp.), peach and apricot (*Prunus* sp.) have been recorded in Illinois nests (Barker 1965, Launer 1967, and Reiss 1971), but other species are probably used. Various functions have been ascribed to this behavior, including: the addition of moisture to the nest chamber, cooling of the nest cavity, concealment of the eggs, and fumigating the nest to discourage ectoparasites. None of these theories has been proved.

The mid-April laying date recorded by Hardy in Southern Illinois may be exceptional (Johnston & Hardy 1962), as it occurred in a particularly mild spring. He believed that more typically the egg-laying

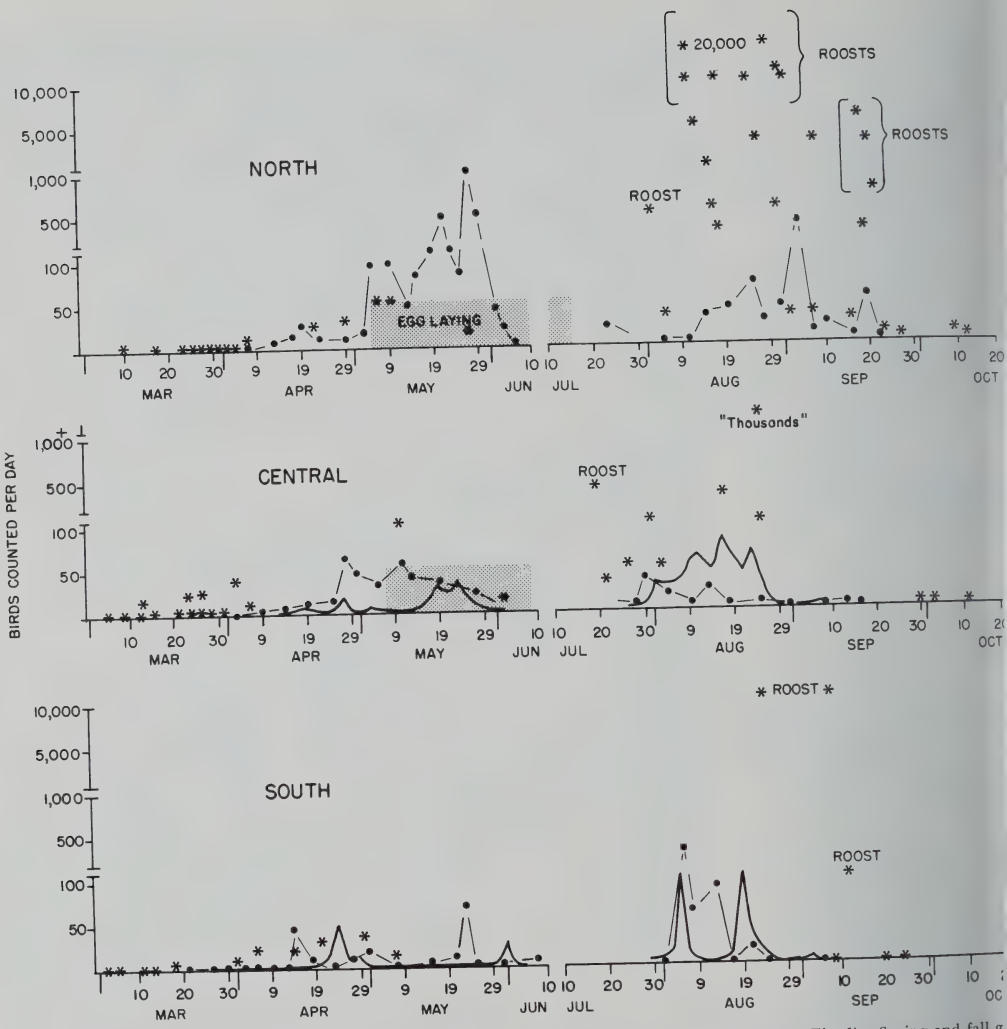

Fig. 29.—Egg-laying and migration seasons of the purple martin in different areas of the state (see Fig. 1). Spring and fall g lines (1967–1970) show the highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other or by other observers. Shaded areas show the span of dates during which egg laying has been recorded. Dot symbols repr counts made on the western side of the state; lines without dots represent the eastern side.

period was from "mid-May" to "early June." Based on fledging and hatching dates (Widmann 1884, and Cooke 1888), egg laying at the St. Louis colonies extended from about April 28 to June 25. In northern Illinois, egg laying has been recorded from May 5 to July 15 (Fig. 29), but the timing of peak production is unknown for any population in the state.

At St. Louis, Widmann (1922) found the usual first clutch to be five eggs, with six eggs in only about 20 percent of the nests, and four eggs the usual clutch for renestings after failures. For northern and cer Illinois we have clutch records for only 12 nest follows: 3 with six eggs, 6 with five eggs, 1 with eggs, and 2 with three eggs. Far more data are ne on this phase of the cycle. Widmann (1922) repo a high incidence (20–25 percent) of "addled" and in northern Illinois Gault (unpublished n recorded an incidence of 17 percent between and 1914.

We have found no published data on nesting

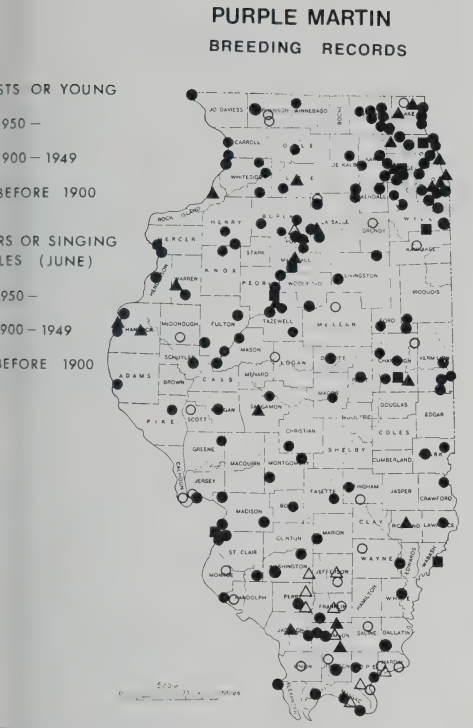

Fig. 30.—Breeding records for the purple martin in Illinois.

or productivity for any Illinois population of purmartins. At St. Louis in 1888, Widmann (1922) rded hatching success of about 58 percent and ging success of 50 percent (of all eggs laid) in a ple of 45 nests with 220 eggs. Widmann believed success was very low for eggs produced in early because of the martins' tendency toward inativeness early in the season, allowing for interfer- from house sparrows, house wrens *(Troglodytes on)*, and other nest usurpers. Though there are erous references to the martins' problems with rows, quantitative data on the effects of sparrows, ns, starlings, or other cavity nesters on martin popions are lacking. Brinkman (1967) described an resting case in which a large colony (21 nest es) of martins flourished in Hoyleton, Illinois for s until the (human) owners of the colony moved y. In succeeding years the boxes were completely n over by starlings. Other species mentioned as competitors or predators are the red-headed dpecker, crested flycatcher *(Myiarchus crinitis)*, jay *(Cyanocitta cristata)*, and bluebird (Ridg- 1915, Reiss 1971, Meany 1945, and Silloway). In urban areas none of the latter species d be considered a significant problem to the martin now, as none of them competes as well as the martin does with sparrows or starlings.

The phenomenon of young martins leaving their nests prematurely is not uncommon, and has been variously ascribed to excessive heat stress, high ectoparasite infestations, and starvation during periods of cool weather (Weber 1954, Widmann 1922, Gault 1934–1935, and Bartel 1946). Widmann and Gault both believed that grounded young martins were usually soon abandoned by the adults; thus it is important for the young to be competent flyers at the time of fledging, and the nestling period is consequently long. Because of the heat problem Gault (1934–1935) and others have emphasized the need for well-ventilated nest boxes, and even the use of double roofs for insulation (Widmann 1905). Persons wishing to attract purple martins with nest boxes should read Widmann (1905), Gault (1934–1935), Bartel (1947), Wade (1968) and Anon. (1968) for valuable information on box design and placement.

References to the production of two or more broods of martins in one year (Eaton 1878, Johnston & Hardy 1962, and Hamilton 1969) have apparently not been based on observation of banded birds. Widmann (1922) was very doubtful of double-broodedness in this species, and Johnston & Hardy (1962) believed that it was very unusual.

Widmann's (1884) day-long observations on the feeding of nestlings are the only quantitative data on this phase of the nesting cycle. He watched 16 nests and found that both parents fed the young, though the female (1,823 feeding trips at all nests) was more active than the male (1,454 feeding trips at all nests). At different nests, each pair made from 20 to 312 trips during the day (4:30 A.M.–8:00 P.M.), depending upon the number and size of the young (312 trips to a nest with four young about 2 weeks old). The youngest birds were fed mainly crushed small beetles, and older nestlings got dragonflies, grasshoppers, and butterflies. In northern Illinois Gault (1934–1935) also observed that butterflies, notably monarchs *(Danaus plexippus)*, and dragonflies, notably the large *Anax junius* were favored as food for young martins. There is no other information on the food of either young or adult martins in Illinois. The often repeated claim that martins eat 2,000 mosquitoes per day is not founded on reliable evidence. Because martins feed on the wing, quantitative determinations of food consumption are extremely difficult to make, but even qualitative determinations based on stomach examinations or field observations are very much needed.

Roosting

By the first of August in Illinois most of the young martins have fledged. Some reach this stage during June in the south (Johnston & Hardy 1962), and late June in the north (Schafer 1922). After fledging, the young, and some adults, often return to roost each

night in the nest box for a time. Widmann (1898) believed that martins tended to leave the nest boxes, even as roosting sites, as soon as possible because of the infestation of mites. He noted that the adult males deserted the box first, then the adult females, and finally the young, after they had been flying about a week. Martins, young and old, may return to the vicinity of the nest box almost daily for at least short periods, particularly mornings or evenings, often well into August, even though they make no apparent use of the box. In this period most martins actually spend the nights at some communal roost.

The communal roosts are most often located in dense groves of trees. Dense willow groves 10–20 feet high along water courses are particularly favored (Widmann 1898), but large roosting or preroosting aggregations have been seen on city buildings, power lines, and sand bars in rivers (Widmann 1922, Tanner 1933, Musselman 1932, White 1933, Wright 1939, and Lobik 1954). A large roost on the Des Plaines River was located in about 30 acres of hawthorn thicket (Craigmile 1939). Typically, the birds mass each evening at the same "staging areas" (power lines, sand bars, etc.), then move, as it is getting dark, to the roosting trees. For excellent accounts see especially Widmann (1922), Anderson (1965), and Lobik (1954). Other species than martins, notably other swallows, starlings, robins, and blackbirds, may share a roost (Craigmile 1939, Bailey 1932, and Taverner 1906).

Loucks (unpublished notes) found a few martins roosting with tree swallows in the Peoria area on June 4, 1893, but notable aggregations at roosts are not usually detected before July, with peak numbers occurring generally in August (Lobik 1954, and Anderson 1965). The roosts vary in size from a few martins to several hundred to tens of thousands (Bailey 1932, Taverner 1906, Smith 1942, Widmann 1898, Anderson 1965, and Hill 1922). Near Arsenal Island (St. Clair County) Widmann (1884) observed a roosting aggregation of 10,000 or more martins on August 24, and though the numbers remained about the same for another 2 weeks, after September 1, an increasing percentage of the birds at the roost were young. Large numbers were still present on September 8, but only about a hundred were left on September 12, and the last few were seen September 18.

Anderson's (1965) observations at a large roost on the Missouri River, near St. Charles, Missouri, show the seasonal build-up and decline of a roosting population. On July 10, at his first visit to the roost, he estimated the martin population to be about 30,000 birds. By August 3 there were 90,000 and on August 13 there were 130,000. After this peak the numbers declined coincidentally with cold-front passage. By August 22 only 900 were left, and all were gone by September 1. The roost in this same area in 1968 peaked at 30,000–40,000 (Hamilton 1968). At a roost in northeastern Illinois, the population peaked (more than 10,000 birds) at the end of August, and declined after the first week in September. By September 1 all but a few were gone (Lobik 1954).

The precise roosting locales may change from year to year, but there appears to be something of a tradition in the general location of large roosts. Two regions with long histories of large roosts are the Chicago area, especially the lake front from North Evanston to Lincoln Park (Evans 1918, White 1933, Wright 1938, and Lobik 1954), and the St. Louis, Missouri area, sites on both sides of the Mississippi River (Widmann 1922, and Anderson 1963). Widmann's (1922) conjecture that the large roosts near St. Louis represent the martin populations of half the states of Missouri and Illinois needs corroboration with banding data. The locations of only a few Illinois roosts have been published.

Fall Migration

Both Widmann (1922) and Anderson (1965) have observed what were apparently late evening (including after dark) migration departures of martins from roost areas, following the passage of cold fronts in August and September. The indication is that fall migration is nocturnal at least in part. Barnes (1938) and Strode (1892) referred to (diurnal?) southward flights in late July and late September in western Illinois, and in the north Gault (unpublished notes 1894) saw a small southward flight at 8:00 A.M. August 17.

Most observers report that the last martins of season are seen around nest boxes during August. The evacuation of roosts occurs in late August and September, as discussed earlier. In extreme southern Illinois Nelson (1877) saw few purple martins in early August, but "immense numbers" in late August. Our counts for southern and central Illinois were relatively high throughout August, but in the north peak numbers were seen in late August and early September (Fig. 29). This is contrary to expectations, as we would expect to see migrant populations later in the south than in the north. However, with the available data we cannot differentiate annual variation in migration from regional variation, if any, and the relatively late migration we observed in the north may have been a matter of annual variation. Such year-to-year variation was noted by Mitchell (1930), who found that in most years some martins at the colony in Hinsdale, Illinois, lingered until August 20, whereas in some years they left in late July or early August. The causes of this variation have not been determined. In some years a few martins have been found in central and northern Illinois in October (Oberholser 1918, Jones 1933, and Robert Russ *fide* Graber 1962), but we have no October records for southern Illinois, a gap which probably reflects the paucity of observers in the south.

The ratios between our spring and fall counts of purple martins show no consistent pattern. In

th we saw three martins in the spring to one in the ; in central Illinois the ratio was even, and in the th we saw one bird in the spring to two in the fall. suspect that martin populations, and swallow pop- tions in general, have a very spotty distribution, ticularly in the fall, with large numbers of birds certain areas and few elsewhere. Such a distribu- n makes it difficult to obtain counts which truly ect the population of a region.

A purple martin banded at Ohio, Illinois, on July 1925, was caught at Sipe Springs in central Texas ut November 23, 1929 (Cooke 1937). This is only published band recovery which indicates nt direction from Illinois, and is also interesting as ngevity record. Even older was a martin banded Columbus, Missouri, on June 18, 1932, and found d almost 6 years later in Hillview, Illinois, May 1938 (Cooke 1942).

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ANNOTATED CHECKLIST OF THE BUTTERFLIES OF ILLINOIS

Roderick R. Irwin • John C. Downey

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NNOTATED CHECKLIST OF THE UTTERFLIES OF ILLINOIS

Roderick R. Irwin and John C. Downey

Illinois has undergone a vast amount of ecological ange since its settlement, and the pace of this change s accelerated in recent years. Change has taken sev-al forms—in agriculture and industry, in metropolitan eas, in highway development, and in the clearing of nd for residential subdivisions and shopping centers. ne widespread use of chemical insecticides and herbi-les is also strongly suspected of having contributed to ological change, and in particular, a decline in but-fly populations.

By the 1860's, when continuous butterfly collecting gan in Illinois, agricultural development of the state s already well advanced, and thus it is difficult to ess its effect on the original butterfly fauna. The other anges are more recent. We believe that at least three tterflies have been extirpated within Illinois. On the ner hand, some species have been added to the Illi-is butterfly fauna.

Ecological succession, a concept well discussed by apiro (1966), and in many cases a result of man's eration of his environment, is discernible in localities ich have been studied for many years. At Streator, La lle County, where Irwin collected for more than 30 rs, a species once locally common, *Anaea andria,* is w rare and has not been taken since 1955, while *losyne gorgone,* not found there at all until 1964, ickly became abundant.

With the increasingly destructive alteration of the vironment by man, it becomes ever more important record conditions as they now exist and to document record by the collecting and proper deposition of ecimens wherever possible. This is the principal ob-tive of this study.

The present survey of Illinois butterflies began in 52, when Downey canvassed the Illinois members of Lepidopterists' Society, seeking distributional data Illinois Lycaenidae (Downey 1966). The encourag-response by Illinois lepidopterists led the authors to and the survey to include all of the 146 butterfly cies that presently occur in the state.

This report is a distributional study, not a manual the identification of Illinois butterflies. Little de-iptive material is included, and then only if the Illi-s population of a species presents special problems not cussed in popular butterfly manuals. One of the st widely used manuals is Klots' field guide (1951), d we recommend that it be used in conjunction with s publication. Nearly all listed species are illustrated this guide by Klots, and, for convenience, references his work are given in the synonymies. Klots men-ned Illinois in the ranges of several species for which there appear to be no Illinois records. Unfortunately, he was unable to locate notes used in the preparation of the field guide in order to support his statements.

At first glance, it might appear that the butterfly fauna of Illinois is relatively uninteresting. However, the great length of the state from north to south and the presence within its borders of three life zones (Merriam 1894), permit establishment of more widely diverse faunae than in most other states. Many Illinois butterflies are statewide in distribution. Transition and even Canadian Zone species such as *Speyeria atlantis, Polygonia faunus,* and *Nymphalis vau-album j-album* occur in extreme northern Illinois. At the southern extremity of the state we find butterfles of distinctly Lower Austral affinities. Some of them are infrequent, e.g. *Atlides halesus,* whereas others are relatively frequent.

The apparent absence of many species in some sections of the state, particularly the northwestern counties, is an illusion created by lack of intensive collecting. The most concentrated collecting in Illinois has been in the Chicago area, where many lepidopterists live. The southern tier of counties has also had relatively good collecting coverage.

METHODS

Our data are presented in the form of an annotated checklist. The scientific name of the species is followed by its common name according to Klots (1951). The synonymy is not intended to be complete but includes a reference to the original description and type-locality, references to names preoccupied or cited in error (designated by double dagger), and references to Worthington (1880), Holland (1931), Klots (1951), and dos Passos (1964, 1969*a,* 1970). We also include references to widely used synonyms not included in the other citations.

Early authors used the term *"in Indiis"* indiscriminately to indicate the habitat of species which they described from either the East or West Indies. We consider this term to refer to the West Indies when it applies to Illinois butterflies.

The distribution of each species known in Illinois from more than six localities is illustrated by a map. Individual records, listed alphabetically by counties, are given for species known from six or fewer localities.

No distinction has been made between records based on specimens actually examined by the authors and those submitted by collaborators or obtained from the literature. All of the latter were carefully evaluated before being accepted, and those which appeared at all questionable were checked by examination of the specimens involved; where this was not possible, the records were not used. Critical determinations were made by specialists studying particular butterfly groups.

In some areas, due to the number and closeness of localities, two or even three nearly adjoining localities

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in the same county may be represented by a single dot on a map.

All butterflies ever actually taken in Illinois have been listed, including such obvious casuals as *Timochares ruptifasciatus, Eumaeus atala, Nymphalis californica, Danaus gilippus strigosus,* and *Phyciodes texana.* We decided against segregating such forms, since they represent valid records. It is obvious that they are not permanent components of the state fauna, but attempting to segregate them would inevitably have resulted in errors of judgment.

The arrangement and nomenclature of the list for the most part follow the latest checklist of the Nearctic butterflies (dos Passos, 1964) and its revisions (dos Passos, 1969*a,* 1970). Departures are explained in the discussion of the species in question. The species numbers are included in the references to the checklist, for example, "dos Passos 1964:3 (No. 24)."

In addition to distributional data, we have presented, in condensed form, some information on ecological preferences, number of broods per season, and dates of earliest and latest capture in Illinois.

DESCRIPTION OF AREA

Early in the 19th century, when settlement of Illinois began, much of the state was forest-covered, but also prominent were vast areas of tall-grass prairie with woodlands along the larger streams. Vestal (1931) divided Illinois into eight vegetational divisions on the basis of the original flora. Jones & Fuller (1955) assembled distributional data and maps of Illinois plants into a volume which, with the supplement by Winterringer & Evers (1960), is indispensable to the student of Illinois butterflies.

Nearly all of Illinois lies within the Upper Austral life zone, but the southern tip of the state is ecologically quite distinct. This consists of the floodplains of the Ohio and Mississippi rivers in Alexander, Pulaski, and Massac counties. Cypress swamps, formerly extensive, are characteristic of this area, which is the most northerly outlier of the Austroriparian subdivision of the Lower Austral zone. Its butterfly fauna has corresponding affinities.

HISTORICAL RESUMÉ

The earliest recorded butterfly observation and collecting in Illinois was done by Edward Doubleday, an eminent English entomologist, who visited the state in the late autumn of 1837. His account of the trip (Doubleday 1838) contains little entomological observation. The insects which Doubleday collected during his journey are now in the British Museum.

The earliest resident worker to make significant contributions to the knowledge of the Illinois butterfly fauna was Benjamin Dann Walsh. The first official State Entomologist of Illinois, he began his studies in 1860 and continued them until his death. He was a correspondent of W. H. Edwards, and supplied the latter with much Illinois material, from which Edwards described at least two butterflies. These descriptions are among the earliest specific references to Illinois butterflies. The main portion of Walsh's collection, following his death, was deposited in the Chicago Academy of Sciences, where it was destroyed in the Chicago fire of 1871. Some of it, however, had been retained by his successor, William Le Baron, and became the nucleus of the present collection of the Illinois Natural History Survey.

Le Baron and Cyrus Thomas, the second and third State Entomologists of Illinois, published notes and incidental references to butterflies in their official reports chiefly from an economic point of view.

Scudder (1869) reported 19 species from Marion Township, Ogle County.

French (1878) discussed 61 Illinois butterflies from the economic standpoint, and in 1879 published the earliest comprehensive state list. It is virtually unknown and exceedingly rare. The copy recently found in the archives of Southern Illinois University is the only one known to us and probably one of very few extant. The list is in the form of a rather primitive key to the Illinois species, of which 113 are included. Ninety-nine of these are considered to have been correctly attributed to Illinois.

Worthington (1880) published a state list of 12 species, of which 109 appear to have been validly included. Snyder (1896) listed 56 species taken at Northwestern Evanston, Cook County, and Hart (1903) listed 50 of the commoner Illinois species. Adams (1915) listed a small number of butterflies in connection with an ecological study in Coles County. C. L. Remington (1943) published an account of the Rhopalocera of Principia College, at Elsah, Jersey County. Wright (1951) listed and figured 11 of the most common Illinois butterflies in a popular manual. Downey (1966) discussed the distribution of Lycaenidae in Illinois. Cushing (1970) listed 56 species from the vicinity of Prairietown, Madison County (one species was incorrectly included). Irwin (1971) gave several new records of Hesperiidae from Illinois, most of which represented important extensions of known ranges.

The remaining papers on the Illinois butterfly fauna (Riley 1870, Wyatt 1905, Frison 1919, C. L. Remington 1942, Conway 1956, Phillips 1961 and 1966, and Irwin 1968) have been limited in scope to one or few species.

Between 1965 and 1969, Irwin prepared various preliminary lists of Illinois butterflies, reproduced by heliograph and Xerox, which were distributed to the various collaborators in this project as a guide to the progress being made. These were cited by Masters (1969). Some of the data they contain have subsequently been revised.

A number of recent Illinois records are contained in the various Field Season Summaries published by the Lepidopterists' Society (C. L. Remington 1947; P. Remington 1948, 1949, 1951; and Heitzman 1968).

A more comprehensive account of the history of butterfly collecting in Illinois and of the principal collections and collections in the state will be published elsewhere as an outgrowth of this study.

SOURCES AND ACKNOWLEDGMENTS

The principal institutions featuring collections of butterflies of Illinois are the Field Museum of Natural History in Chicago and the Illinois Natural History Survey in Urbana. Smaller collections are found in other museums and in various state universities.

Individual collections at the Field Museum are the

f S. Camras, A. Herz, D. H. Kistner, E. F. Lustig, A. L. IcElhose, A. Sala, A. J. Snyder, H. Strecker, and A. K. Vyatt.

The most comprehensive collection of Illinois butterflies is at the Illinois Natural History Survey. Individual ollections deposited in the Survey collection are those f R. M. Barnes (in part), E. Beer, A. Bolter, R. R. rwin, A. Mares, A. H. Mundt (via the Irwin and R. M. arnes collections), W. A. Nason, S. H. Peabody, O. T. lumb (via the Irwin collection), Charles Robertson, nd G. W. Wren (including the Margaret M. Cary utterflies).

The Illinois State Museum at Springfield contains a nall general collection. The major portion consists of ie bulk of the R. M. Barnes collection, together with ie Chicago area collection of J. W. E. Glattfeld and me local material.

Southern Illinois University at Carbondale possesses n excellent collection of southern Illinois butterflies. here is no longer any G. H. French material at this stitution, despite his long service on its staff; the only tant French butterflies are in other collections.

The above institutional collections cited, and others om which fewer records were obtained, are abbreviated follows: AMNH (American Museum of Natural Hisry, New York City, New York); CM (Carnegie Muum, Pittsburgh, Pennsylvania); FMNH (Field Museum Natural History, Chicago, Illinois); INHS (Illinois atural History Survey, Urbana); ISM (Illinois State luseum, Springfield); SIU (Southern Illinois Univerty, Carbondale); USNM (United States National Muum, Washington, D. C.).

The collaborators whose contributions constitute a rge proportion of the records obtained during the surey are identified by the following abbreviations: RAA Richard A. Arnold, Hinsdale, Illinois); JKB (John . Bouseman, Champaign, Illinois); JLB (Jackson L. oughner, Chicago, Illinois); TGB (Thomas G. Brady, a Grange, Illinois); GC (Gary Christoph, Chicago, linois); PJC (Patrick J. Conway, Chicago, Illinois); CD (John C. Downey, Cedar Falls, Iowa); TE (Theore Ellis Jr., Danville, Illinois); MOG (Murray O. lenn, Henry, Illinois); JRH (J. R. Heitzman, Indendence, Missouri); RRI (Roderick R. Irwin, Chicago, linois); DL (Don Laibly, Rock Island, Illinois); RL Ronald Leuschner, Gardena, California); GMcC (Gary IcCoy, Park Forest, Illinois); GN (Gregory Nielsen, nicago, Illinois); LSP (the late Leonard S. Phillips, heaton, Illinois); OAP (Owen A. Perkins, Royal Oak, ichigan); CLR (Charles L. Remington, New Haven, onnecticut); LS (Larry Schatz, Elmwood, Illinois); GS (Norman G. Seaborg, Lockport, Illinois); VGS . G. Sasko, Chicago, Illinois); TT (Thomas Taylor, oria, Illinois); AKW (the late Alex K. Wyatt, Chigo, Illinois); CW (Colin W. Wyatt, Farnham, Sury, England). We express our very sincere gratitude these collaborators, and to the following other individls: Gordon L. Adams, Karl R. Gardner, David F. ess, Kurt Johnson, M. C. Nielsen, P. S. Remington, seph Roberds, Frank Rutkowski, and Michael J. Smith. ithout their cordial assistance the completion of this rvey would have been impossible.

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BUTTERFLIES OF ILLINOIS

HESPERIIDAE

Panoquina ocola (Edwards)
Ocola skipper

Hesperia ocola Edwards 1863*a*:20 (type-locality "Georgia, Florida and Texas").
Prenes ocola: Holland 1931:398.
Panoquina ocola: Klots 1951:270; dos Passos 1964:3 (No. 24).

Illinois records.—Jersey County: Pere Marquette State Park, September 10, 1935, Lauck (CW).

We have not seen this specimen, but we believe the record to be valid. The species probably occurs at least occasionally in the southern counties.

Calpodes ethlius (Stoll)
Brazilian skipper

Papilio ethlius Stoll 1782(4):212 (type-locality "Surinam").
Calpodes ethlius: Holland 1931:399; Klots 1951:269; dos Passos 1964:3 (No. 27).

Illinois records.—Cook County: Chicago, emerged August 27 and August 29, 1923, from larvae found on *Canna,* Dohmen (FMNH).

This skipper is probably not established anywhere in Illinois, occurring only when introduced on *Canna,* or perhaps occurring casually in extreme southern Illinois.

Lerodea eufala (Edwards)
Eufala skipper

Hesperia eufala Edwards 1869:311 (type-locality "Apalachicola, Florida").
Lerodea eufala: Holland 1931:396; Klots 1951:267; dos Passos 1964:3 (No. 29).

Illinois records.—Kane County: Elgin, September 21, 1941, September 20, 1942, Wyatt (FMNH); Elgin, September 20, 1942, Beer (INHS). Marshall County: Lacon, September 28, 1931, R. M. Barnes (INHS). Putnam County: October 1, 1931, Glenn (INHS).

Apparently *eufala* is rare and casual in northern Illinois. It should also be found in southern Illinois, since it is a species of southern affinities.

Amblyscirtes linda H. A. Freeman
Linda's roadside skipper

Amblyscirtes linda H. A. Freeman 1943:19 (type-locality "Hope Hill Farm, Faulkner County, Arkansas"); Klots 1951:264.
Amblyscirtes aenus linda: dos Passos 1964:4 (No. 34b).

Illinois records.—Jackson County: Makanda, July 8, 1896, Snyder (FMNH).

We found the only known Illinois specimen of *linda* in the series of *A. belli* H. A. Freeman in the Field Museum collection. It was sent to Freeman, who confirmed our determination. We separate *linda* from *A. aenus* Edwards on the advice of Freeman (personal communication). In the absence of additional records, it is difficult to evaluate the status of *linda* and some of the other species of the genus in Illinois. They may be established elements of the fauna, or they may be casuals from further south.

Amblyscirtes samoset (Scudder)
Pepper and salt skipper

Hesperia samoset Scudder 1864:176 (type-locality "Massachusetts and New Hampshire").
Hesperia hegon Scudder 1864:176 (type-locality "White Mountains [New Hampshire]").
Amblyscirtes samoset: Worthington 1880:49; Holland 1931:362; dos Passos 1964:4 (No. 37).
Amblyscirtes hegon: Klots 1951:263.

Illinois records.—Map 1.

Widely scattered records are indicative of statewide distribution, but the species is apparently local and uncommon in Illinois. There are a number of records from Cook County, but none is recent (FMNH). Snyder (1896) found *samoset* "rare" at Evanston, Cook County. There is one brood, April 12 through June 19.

Amblyscirtes aesculapius (Fabricius)
Textor skipper

Hesperia aesculapius Fabricius 1793:347 (type-locality "North America").
Pyrgus textor Hübner "1818" [1827-1831]: Plate 580 (type-locality "United States").
Amblyscirtes textor: Holland 1931:363; Klots 1951:263.
Amblyscirtes aesculapius: dos Passos 1964:4 (No. 40).

Illinois records.—Pope County: Lusk Creek, near Eddyville, July 7, 1967, August 9, 1967, August 30, 1967 Downey (SIU). Union County: Pine Hills, Augus 21, 1966, August 25, 1966, September 1, 1966, Downey determined by H. A. Freeman (INHS) (Fig. 1).

As in the case of other species of this genus, it is dif ficult to assess the status of *aesculapius* in Illinois, bu the number of records suggests that it is established i extreme southern Illinois.

Amblyscirtes carolina (Skinner)
Carolina roadside skipper

Pamphila carolina Skinner 1892:222 (type-localit "south of Hamlet, Richmond County, North Car lina").
Amblyscirtes carolina: Holland 1931:362; Klots 195 263; dos Passos 1964:4 (No. 41).

Illinois records.—Union County: Pine Hills, Se tember 1, 1966, Downey, determined by H. A. Freem (INHS) (Fig. 1).

This record extends the known range of this ski per, recorded previously from Georgia to Virginia (Klo 1951) and Mississippi (Mather & Mather 1958).

Amblyscirtes vialis (Edwards)
Roadside skipper

Hesperia vialis Edwards 1862*a*:58 (type-locality "Ro Island, Illinois; Lake Winnipeg").
Amblyscirtes vialis: Worthington 1880:49; Holla 1931:362; Klots 1951:262; dos Passos 1964:4 (N 45).

Illinois records.—Map 2.

A. vialis is apparently widely distributed in Illinois b very local. It may be common where found, as at Els Jersey County (CLR) and Mason State Forest, Ma County (TT). Elsewhere, however, it is scarce (Per Township, Mercer County) (PJC) or absent altogeth The dates of capture in Illinois suggest that there are t broods: April 21 through May 30 and July 17 throu August 30.

Amblyscirtes belli H. A. Freeman
Bell's roadside skipper

Amblyscirtes belli H. A. Freeman 1941:50 (type-loca "Lancaster and two miles west of Vickery, Da County, Texas"); Klots 1951:264.
Amblyscirtes celia belli: dos Passos 1964:5 (No. 46b)

Illinois records.—Pope County: Lusk Creek, n Eddyville, August 9, 1967, Downey, determined by H Freeman (INHS).

We give *belli* full specific rank on the advice of H Freeman, who said (personal communication to L Paulissen) that "there are no subspecies in that genu . . . *celia* and *belli* fly together in Texas."

Atrytonopsis hianna (Scudder)
Dusted skipper

Hesperia hianna Scudder 1868*a*:382 (type-loc "Quincy and Dorchester, Massachusetts").
Atrytonopsis hianna: Holland 1931:394; Klots 1 259; dos Passos 1964:5 (No. 50).

Illinois records.—Bureau County: Ohio Township
G. M. Dodge?) (Scudder 1889). Cook County: Chi-
go, May 24, 1896, Wyatt (FMNH); no date, West-
tt (INHS). Greene County: 2 mi. S Eldred, May
1963, Sanderson (INHS). Jersey County: Pere
arquette State Park, September 16, Lauck (CW).
PE County: Lusk Creek, near Eddyville, May 20,
68, Downey (INHS). Scott County: W of Glas-
w, May 2, 1963, Sanderson (INHS).

This skipper is apparently single-brooded; the Sep-
nber record from Jersey County is unusual. We have
t seen the specimen on which it was based, and the
cord may be erroneous. It appears from the available
ta that *hianna* is widely distributed but rare and er-
ic in Illinois.

Euphyes dion (Edwards)
Dion skipper

mphila dion Edwards 1879:238 (type-locality "south-
ern shore of Lake Michigan, in Indiana; Hamilton,
Ontario"); Worthington 1880:49.
ytone dion: Holland 1931:388; Klots 1951:255.
phyes dion: dos Passos 1964:6 (No. 62).

Illinois records.—Cook County: Winnetka, July 28,
58, Irwin (INHS) (Fig. 1); Teasons Woods Forest
eserve, 3 mi. NW Palos Park, 14 ♂♂ 2 ♀♀, July 8,
66, Arnold, Brady, and Irwin (RAA, TGB, INHS)
ig. 1); locality not stated, July 15, 1959, July 7, 1960,
y 4, 1962, July 7, 1962, Boughner (JLB). Cham-
GN County: Urbana, July 3, 1891, Mitchell
NHS). Lake County: Waukegan, July 31, 1943,
RZ (FMNH).

This insect is apparently restricted to northeastern
nois and is mainly limited to marshes and boggy
adows. It is local and generally scarce but may oc-
in some numbers where found. It is probably sin-
-brooded.

Euphyes dukesi (Lindsey)
Dukes' skipper

ytone (Euphyes) dukesi Lindsey 1923:209 (type-
locality "Mobile County, Alabama").
ytone dukesi: Holland 1931:388; Klots 1951:255.
phyes dukesi: dos Passos 1964:6 (No. 63).

Illinois records.—Pulaski County: Karnak, Sep-
ber 2, 1924, Frison (INHS) (Fig. 1). Union Coun-
Pine Hills, September 10, 1966, Downey, deter-
ed by H. A. Freeman (INHS); Pine Hills, August
1969, Irwin (INHS) (Fig. 1).

It appears that this distinctive skipper is established
southern Illinois. The record from Pulaski County
the first following its original description (Irwin
1).

E. dukesi was once believed to be restricted to swamps
their immediate vicinity, but it has recently been
nd, in the southern portions of its range, in drier
ations as well. Two sedges, *Carex lacustris* and *C.*
linolepis, are the probable hosts of *dukesi.* Both sedges
ur in Illinois, the former being more confined to true
mp environments than is the latter. In the southern
tion of the range of *dukesi, C. lacustris* does not occur
the insect utilizes *C. hyalinolepis* (Irwin 1972). Be-
se of the rather wide occurrence of both sedges in the
state and the presence of *dukesi* as far north as Michi-
gan, it seems possible that the skipper may occur else-
where than in the extreme southern counties.

Euphyes conspicua (Edwards)
Black dash

Hesperia conspicua Edwards 1863*a*:17 (type-locality
"Lansing, Michigan").
Hesperia pontiac Edwards 1863*a*:17 (type-locality "Lan-
sing, Michigan").
Pamphila pontiac: Worthington 1880:49.
Atrytone pontiac: Holland 1931:388.
Atrytone conspicua: Klots 1951:258.
Euphyes conspicua: dos Passos 1964:6 (No. 64).

Illinois records.—Map 3.

This is another species that is found mainly in marsh-
es and boggy meadows. It is local but may be common
where found. It is apparently limited to northern Illi-
nois. There is one brood, June 20 through August 9.

Euphyes bimacula (Grote & Robinson)
Two-spotted skipper

Hesperia bimacula Grote & Robinson 1867*c*:433 (type-
locality "Philadelphia, Pennsylvania").
Hesperia illinois Dodge 1872:217 (type-locality "Bureau
County, Illinois").
Pamphila bimacula: Worthington 1880:49.
Atrytone bimacula: Holland 1931:388; Klots 1951:258.
Euphyes bimacula: dos Passos 1964:6 (No. 66).

Illinois records.—Map 4.

E. bimacula (Fig. 1) is sporadic but locally common.
Like other members of the genus, it occurs in bogs and
wet meadows, and it appears to be limited to the north-
ern portion of the state. See discussion of *Oarisma*
powesheik (Parker), below. The species is single-brood-
ed, June 19 through July 20.

Euphyes vestris metacomet (Harris)
Dun skipper

Hesperia metacomet Harris 1862*b*:317 (type-locality
"Massachusetts").
Pamphila rurea Edwards 1862*a*:58 (type-locality "Rock
Island, Illinois").
Pamphila metacomet: Worthington 1880:49.
Atrytone ruricola: Holland 1931:388; Klots 1951:258.
Euphyes vestris metacomet: dos Passos 1964:6 (No.
67b).

Illinois records.—Map 5.

The dun skipper is common and generally distributed
throughout Illinois. Although Klots (1951) suggested
that there is but one brood and gave dates of flight from
June through August, we have records of the species
from April 28 through September 16. This extended
flight period strongly suggests that the species is at least
double-brooded in Illinois.

Poanes massasoit (Scudder)
Mulberry wing

Hesperia massasoit Scudder 1864:171 (type-locality
"Carver, Massachusetts; Connecticut, New Eng-
land").

Pamphila massasoit: Worthington 1880:49.
Poanes massasoit: Holland 1931:389; Klots 1951:249; dos Passos 1964:7 (No. 72).

Illinois records.—Kane County: Elgin, many specimens and dates, June 28 through August 15, Bristol and Herz (FMNH, INHS). Iroquois County: 2 mi. NE Beaverville, June 29, 1965, Irwin (INHS) (Fig. 1). McHenry County: McHenry Dam State Park, July 17, 1971, Christoph (GC).

Although *massasoit* is known from few localities, it is doubtlessly found elsewhere in suitable habitats in the northern half of the state. At Beaverville, Iroquois County, we found it flying in company with *Euphyes bimacula.* Like that species, *massasoit* is an inhabitant of bog and marsh environments. It is local but may be common where found. There is probably only one brood.

Poanes hobomok (Harris)
Hobomok skipper

Hesperia hobomok Harris 1862*b*:313 (type-locality "Massachusetts").
Poanes hobomok: Holland 1931:390; Klots 1951:250; dos Passos 1964:7 (No. 73).

Illinois records.—Map 6.

P. hobomok is generally distributed throughout Illinois, although records are few and widely scattered. It is common where found. The species has been confused with *P. zabulon,* rendering many older records in the literature unreliable. It is single-brooded. The earliest and latest dates of capture are May 20 and July 4.

The females are dimorphic; most are similar to the males, but the dark female form *pocahontas* is occasionally found. The dark form does not appear to be common in Illinois and may not occur throughout the state. The only localities from which it has been recorded are Palos Park (Fig. 1) and River Grove, in Cook County, between June 2 and July 1.

Poanes zabulon (Boisduval & Le Conte)
Zabulon skipper

Hesperia zabulon Boisduval & Le Conte 1834: Plate 76 (type-locality "North America").
Pamphila zabulon: Worthington 1880:49.
Poanes zabulon: Holland 1931:390; Klots 1951:250; dos Passos 1964:7 (No. 74).

Illinois records.—Map 7.

Like *P. hobomok, zabulon* appears to be distributed throughout Illinois. It is, however, less common than the foregoing species. Both *hobomok* and *zabulon* are less restricted in habitat than their congeners and are not confined to marsh environments. Unlike *hobomok, zabulon* is double-brooded. The first brood is smaller in numbers than the second and has been recorded from May 5 through July 8. The second brood is larger, appearing in early August and reaching maximum numbers 3 weeks later. Earliest and latest dates for the second brood in Illinois are August 9 and September 13.

Poanes viator (Edwards)
Broad winged skipper

Hesperia viator Edwards 1865:202 (type-locality restricted to "Goose Lake Prairie, Grundy County, Illinois" by Shapiro "1970" [1971]:110 by designation of neotype) (Fig. 1).
Pamphila viator: Worthington 1880:49.
Phycanassa viator: Holland 1931:392.
Poanes viator: Klots 1951:249; dos Passos 1964:7 (No. 78).

Illinois records.—Grundy County: Goose Lak Prairie, July 28, 1969, 1 ♂ 1 ♀, Cashatt (INHS). Mc Henry County: McHenry Dam State Park, July 17 1971, 2 ♂♂ 2 ♀♀, Christoph and Nielsen (GC, GN)

Before the recent rediscovery of this skipper in north ern Illinois, the only indication of its presence in th state was Edwards' designation of "Northern Illinois an New Orleans" as the original type-locality. Shapiro con ducted an extensive search of major institutional colle tions but found no syntypes or other Illinois *viator.* H therefore designated the male specimen from Grund County listed above as the neotype of the species (Sha piro, *loc. cit.*).

Search for *viator* at the Goose Lake locality in 197 and 1971 did not produce any additional examples, b it was discovered in McHenry County. It may occ in similar marsh habitats elsewhere in northern Illino It is single-brooded and very local. The flight is sa by Conway (personal communication) to resemble th of *P. massasoit.*

Problema byssus (Edwards)
Byssus skipper

Pamphila byssus Edwards 1880*b*:224 (type-locality "I dian River, Florida").
Problema byssus: Holland 1931:386; Klots 1951:2 dos Passos 1964:8 (No. 83).

Illinois records.—Jersey County: Elsah (camp of Principia College), July 5, 1942, July 7, 1942, Ju 27, 1943, P. S. Remington (P. Remington 1956). Salle County: Streator, July 20, 1963, McC (INHS); Streator, July 20, 1964, Irwin (INHS) (I 1). Mason County: Mason State Forest, July 1963, July 19, 1963, Taylor (TT). Mercer Coun Perryton Township ("local, common when found, June – early July") (PJC). Monroe County: 3 S Valmeyer, June 27, 1956, Sanderson (INHS). Pe County: Robinson Park, 10 mi. N Peoria, July 7, 19 Taylor (TT).

The lack of old records suggests that this may b comparatively recent addition to the Illinois fauna, p ably adventive from west of the Mississippi rather t from the South. It appears to be gradually increa its range in Illinois following the larger rivers, or near which most of the known examples of *byssus* in nois have been found. Some authors regard this prairie species, but its apparent prosperity in Illinois indicate that it is adapting to a more varied habita

Atrytone delaware (Edwards)
Delaware skipper

Hesperia delaware Edwards 1863*a*:19 (type-loc "Philadelphia [Pennsylvania]").
Hesperia logan Edwards 1863*a*:18 (type-locality " sing, Michigan").
Pamphila delaware: Worthington 1880:49.
Atrytone logan: Holland 1931:387; Klots 1951:2

rytone delaware: dos Passos 1964:8 (No. 86).

Illinois records.—Map 8.

The Delaware skipper has been recorded from scat-ed localities throughout Illinois. It probably occurs er the entire state but is not common. Females super-ially resemble the male of *Problema byssus*. It is obably single-brooded, June 17 through August 30.

Atalopedes campestris (Boisduval)
Sachem

speria campestris Boisduval 1852:316 (type-locality "California").
speria huron Edwards 1863*a*:16 (type-locality "Illi-nois, Georgia, Texas, Washington, D. C.").
mphila huron: Worthington 1880:49.
alopedes campestris: Holland 1931:385; Klots 1951: 243; dos Passos 1964:9 (No. 87).

Illinois records.—Map 9.

This insect is common and generally distributed oughout Illinois. It is a characteristic species of late mmer and autumn. We have records from May 23 robably overwintered individuals) through November with maximum abundance in August and September.

Pompeius verna (Edwards)
Little glassy wing

nphila verna Edwards 1862*a*:57 (type-locality "Illi-nois; Washington [D. C.]").
nphila pottawattomie Worthington 1880:50 (type-locality "Chicago, Illinois; Lake County, Indiana").
nphila verna: Worthington 1880:49.
ites verna: Holland 1931:380; Klots 1951:245.
mpeius verna: dos Passos 1964:9 (No. 88).

Illinois records.—Map 10.

P. verna is common and generally distributed oughout Illinois. According to Klots (1951), *verna* ingle-brooded, but we have records from May 12 ough September 9, indicating the possibility of a nd brood. The skipper becomes most common in -June and remains numerous through mid-July.

Wallengrenia egeremet (Scudder)
Broken dash

peria egeremet Scudder 1864:174 (type-locality "Massachusetts, Georgia, Western States, New Eng-land").
nphila egeremet: Worthington 1880:49.
ia otho egeremet: Holland 1931:386.
llengrenia otho egeremet: Klots 1951:248; dos Pas-sos 1964:9 (No. 89b).

Illinois records.—Map 11.

The broken dash is a common skipper throughout ois. Most authors consider it a subspecies of *W. otho* E. Smith), but Forbes (1960) gave it full specific s and illustrated genitalic differences which appear to distinctive. Dr. L. J. Paulissen informed us (personal munication) that *otho* and *egeremet* occur together rkansas "with no apparent or obvious intergrading, iterion of speciation." *W. egeremet* is single-brooded. have records from June 2 through August 17.

Polites coras (Cramer)
Peck's skipper

Papilio coras Cramer 1775(1):51 (type-locality "Suri-nam").
Hesperia peckius Kirby 1837:300 (type-locality "North America").
Pamphila peckius: Worthington 1880:49.
Polites peckius: Holland 1931:382; Klots 1951:246.
Polites coras: dos Passos 1964:9 (No. 90).

Illinois records.—Map 12.

This skipper is exceedingly common and generally distributed throughout Illinois. *P. coras* and the next species are the most abundant skippers of the state. Earliest and latest dates are April 16 and October 3.

Polites themistocles (Latreille)
Tawny edged skipper

‡*Papilio taumas* Fabricius (*nec* Hufnagel) 1787:84 (type-locality "North America").
‡*Papilio thaumas* Fabricius (*nec* Hufnagel) 1793:327.
Hesperia themistocles Latreille "1819" [1824]:769 (type-locality "southern America").
Hesperia cernes Boisduval & Le Conte 1834: Plate 76 (type-locality "North America").
Pamphila cernes: Worthington 1880:49.
Polites taumas: Holland 1931:381.
Polites themistocles: Klots 1951:245; dos Passos 1964:10 (No. 95).

Illinois records.—Map 13.

Like the preceding species, *P. themistocles* is very abundant and occurs throughout Illinois. Records are at hand from April 29 through September 29.

Polites origenes (Fabricius)
Cross line skipper

Hesperia origenes Fabricius 1793:328 (type-locality "West Indies").
Hesperia cernes Harris (*nec* Boisduval & Le Conte) 1862*b*:316 (type-locality "Massachusetts, Southern States").
Hesperia manataaqua Scudder 1864:175 (new name).
Pamphila manataaqua: Worthington 1880:49.
Polites manataaqua: Holland 1931:380; Klots 1951:245.
Polites origines: dos Passos 1964:10 (No. 96) (*lapsus calami*).

Illinois records.—Map 14.

P. origenes is far less numerous than *themistocles,* which it closely resembles, but is still of fairly frequent occurrence. Records, although scattered, indicate a general distribution throughout Illinois. Dates of capture are from June 4 through September 1.

Polites mystic (Edwards)
Long dash

Hesperia mystic Edwards 1863*a*:15 (type-locality "Connecticut, Michigan, Canada West").
Pamphila mystic: Worthington 1880:49.
Polites mystic: Holland 1931:383; Klots 1951:247; dos Passos 1964:10 (No. 97).

Illinois records.—Map 15.

P. mystic is apparently limited to northeastern Illinois. It is locally frequent. We follow Brown (1966*c*) in ascribing the authorship of *mystic* to Edwards rather than Scudder. The species is single-brooded, from May 22 through July 15. Most records are from mid-June.

Hesperia ottoe Edwards
Ottoe skipper

Hesperia ottoe Edwards "1866" [1867]:207 (type-locality "Kansas"); Klots 1951:239; dos Passos 1964:12 (No. 112).
Erynnis ottoë: Holland 1931:374.

Illinois records.—Lake County: Waukegan, July 28, 1946, 1 ♀, Wyatt (FMNH). Mason County: Mason State Forest, July 19, 1963, 1 ♀, Taylor, determined by H. A. Freeman (INHS) (Fig. 1); Mason State Forest, July 11, 1964, 1 ♀, July 19, 1964, 8 ♂♂ 3 ♀♀, Taylor (TT).

Irwin (1971) has noted the recent discovery of this species in Illinois. The status of *ottoe* in Illinois is uncertain. All specimens taken in Illinois have been found in sand areas.

Hesperia dacotae (Skinner)
Dakota skipper

Pamphila sassacus dacotae Skinner 1911:412 (type-locality "Volga, South Dakota").
Erynnis dakotae: Holland 1931:374.
Hesperia dacotae: Klots 1951:238; dos Passos 1964:12 (No. 113).

H. dacotae was credited to Illinois by Klots (1951: 237, key to *Hesperia*). There are three specimens of *dacotae* in the Carnegie Museum from Illinois. They are a male, labeled in part "Ridgeland, 1895, W. E. Longley," from the A. W. Lindsey collection; another male, very dirty, labeled "sassacus ♂/Ills." in the hand of W. H. Edwards; and a female, labeled in part "No. Ill. 1889" and "Hesperia dacotae ♀ Skin. det. A. W. Lindsey 1940." We assume that Lindsey also examined the other two specimens listed and rely upon his determinations. These specimens may have been the basis for Klots' record. Ridgeland, in 1895, was a station on the Chicago and North Western Railroad, about one mile east of Oak Park, Cook County. The status of *dacotae* in Illinois at the present time is unknown. In view of the great ecological change in the Chicago area since the late 19th century, it would appear most unlikely that a prairie species such as *dacotae* would have been able to maintain itself there, but the recent finding of *Hesperia ottoe* in the state may belie this assumption. Perhaps it occurs elsewhere in northern Illinois, especially in the extreme northwestern portion of the state. Lindsey, Bell, & Williams (1931) did not mention Illinois in their discussion of *dacotae*, but it may be that Lindsey was unaware at that time of the existence of the Illinois specimens.

Hesperia sassacus Harris
Indian skipper

Hesperia sassacus Harris 1862*b*:315 (type-locality "Massachusetts"); Klots 1951:238; dos Passos 1964:12 (No. 114).
Pamphila sassacus: Worthington 1880:49.
Erynnis sassacus: Holland 1931:373.

Illinois records.—Cook County: Evanston, June 2[illegible] 1896, Snyder (FMNH). *H. sassacus* should be of mor[illegible] frequent occurrence in Illinois than the single recor[illegible] indicates. Worthington indicated personal knowledge o[illegible] its capture in Illinois. We have numerous records fro[illegible] nearby localities in northwestern Indiana.

Hesperia leonardus Harris
Leonard's skipper

Hesperia leonardus Harris 1862*b*:314 (type-locali[illegible] "Massachusetts"); Klots 1951:237; dos Passos 196[illegible] 12 (No. 117).
Pamphila leonardus: Worthington 1880:49.
Erynnis leonardus: Holland 1931:376.

Illinois records.—Cook County: Spears Woo[illegible] Forest Preserve, September 4, 1972, Irwin and Seabo[illegible] (INHS, NGS). Mason County: Mason State Fore[illegible] September 1, 1963, September, 1964, Taylor (INH[illegible] TT). Peoria County: Kickapoo Creek, 1956, Tay[illegible] (TT). Vermilion County: Danville, August 24, 19[illegible] Ellis and Irwin (TE, INHS) (Fig. 1).

This distinctive late-summer and autumn spec[illegible] should be more numerous and widespread in Illin[illegible] than these few records indicate. There is one bro[illegible] flying exclusively in late August and September.

Hylephila phyleus (Drury)
Fiery skipper

Papilio phyleus Drury 1773(1):25 (type-locality "[illegible] tigua, St. Christopher's, Nevis, etc.").
Pamphila phylaeus: Worthington 1880:49.
Hylephila phylaeus: Holland 1931:377.
Hylephila phyleus: Klots 1951:243; dos Passos 1964 (No. 122).

Illinois records.—Map 16.

Scattered records of this species are at hand throu[illegible] out Illinois. It is fairly common in late summer [illegible] autumn. There are a few early season records, perh[illegible] representing overwintering individuals. It has been [illegible] served May 14 through October 9, with most rec[illegible] in September.

Thymelicus lineola (Ochsenheimer)
European skipper

Papilio lineola Ochsenheimer 1808:230 (type-loc[illegible] "Germany").
Adopaea lineola: Holland 1931:366; Klots 1951:2[illegible]
Thymelicus lineola: dos Passos 1964:14 (No. 123)

Illinois records.—Map 17.

This introduced European species (Fig. 1) is [illegible] cent adventive in Illinois. Much interest has atta[illegible] to its spread in North America since its presence wa[illegible] covered in 1910. First found in the Chicago are[illegible] 1957, *lineola* is now well established in several loc[illegible] there; new ones are found each year. The specie[illegible] pears to be expanding its range beyond the Ch[illegible] metropolitan area and in time will probably s[illegible] throughout the state (Irwin 1968). It sometimes re[illegible] enormous abundance in a very restricted locality, ex[illegible]

g in numbers all other butterflies during the height of s flight period. *T. lineola* occurs in many habitats and as been taken in vacant lots and along railroad tracks ithin the city of Chicago. The species is single-brooded, ppearing shortly after the middle of June (earliest date ne 15). It quickly reaches a peak of abundance, then adually diminishes, and disappears about the middle of ly. The latest date of capture is July 14, but few speciens have been noted after the first week of July. It ill be of interest to note the possible effect on our tive grass-feeding skippers of the increase and spread this species—comparable, perhaps, to that of *Pieris pae* on the native species of that genus.

Oarisma powesheik (Parker)
Powesheik skipper

esperia powesheik Parker 1870:271 (type-locality "Grinnell, Iowa").
arisma powesheik: Holland 1931:360; Klots 1951:231; dos Passos 1964:14 (No. 127).

The only evidence of the occurrence of this skipper Illinois is found in Dodge (1872). In the original scription of *Hesperia illinois* (= *Euphyes bimacula*), said: "This species [*illinois*] was discovered by Mr. A. Dodge, in Burcan [Bureau] County, Illinois. The st specimen was taken June 20, 1872. It was quite undant upon grassy slopes on the high rolling prairie at forms the divide between the Illinois and Rock ers. . . Two weeks later *Hesperia Powesheik,* Parker, peared abundantly in the same locality." Klots (1951) tributed *O. powesheik* to northern Illinois, possibly the basis of this record. Blatchley (1891) recorded from Whiting, Lake County, Indiana, saying that it "a western species not before recorded east of Illinois." French (1879) and Worthington (1880) did not list *wesheik* from Illinois, despite the earlier record of dge, but they did include "*Thymelitus*" *garita* (Reat). The two species are congeneric and have been nfused in the past. We regard it as probable that these thors referred to *powesheik*; it is unlikely that true *O. rita* occurs as far east as Illinois.

The area described by Dodge has not been well colted, and *powesheik* may still occur in local colonies. the absence of specimens on which the Dodge record s founded, the possibility that they were incorrectly ntified cannot be ruled out, although it is difficult imagine with what other insect Dodge could have nfounded this distinctly marked form.

Ancyloxypha numitor (Fabricius)
Least skipper

speria numitor Fabricius 1793:324 (type-locality "West Indies").
cyloxypha numitor: Worthington 1880:48; Holland 1931:367; dos Passos 1964:14 (No. 130).
cyloxipha numitor: Klots 1951:231.
cyloxypha longleyi French 1897:80 (type-locality "Ridgeland, west of Chicago, Illinois").

Illinois records.—Map 18.

This diminutive skipper is common and generally tributed throughout Illinois. It occurs principally ong tall grasses bordering streams and roadside ches. There are at least two broods, with dates from May 18 through September 28. French applied the name *longleyi* to the color variety, frequently occurring with typical *numitor,* having the fore wings solidly black.

Lerema accius (J. E. Smith)
Clouded skipper

Papilio accius J. E. Smith 1797:45 (type-locality "[probably Screven County,] Georgia").
Lerema accius: Holland 1931:396; Klots 1951:260; dos Passos 1964:15 (No. 134).

Illinois records.—Jackson County: Carbondale, August 24, 1880, French (AMNH via A. B. Klots).

More intensive collecting in southern Illinois would probably reveal that this species is found in the extreme southern counties as a casual adventive.

Nastra lherminier (Latreille)
Swarthy skipper

Hesperia lherminier Latreille "1819" [1824]:777 (type-locality "Carolina").
Hesperia fusca Grote & Robinson 1867*a*:2 (type-locality "Atlantic District").
Megistias lherminieri: Holland 1931:395.
Lerodea l'herminieri: Klots 1951:266.
Nastra lherminier: dos Passos 1964:16 (No. 137).

Illinois records.—Madison County: Alton, July 26, 1941, Lauck, (CW). Pope County: Lusk Creek, near Eddyville, July 31, 1967, August 5, 1967, Downey, determined by H. A. Freeman (INHS). Vermilion County: Danville, August 20, 1967, Irwin, determined by H. A. Freeman (INHS) (Fig. 1).

This small and undistinguished species is probably commoner in the southern portion of Illinois than the few records would indicate. It may be overlooked because of its diminutive size and drab appearance.

Pholisora catullus (Fabricius)
Common sooty wing

Hesperia catullus Fabricius 1793:348 (type-locality "West Indies").
Pholisora catullus: Worthington 1880:49; Holland 1931:345; Klots 1951:218; dos Passos 1964:17 (No. 148).

Illinois records.—Map 19.

This butterfly is common to abundant everywhere in Illinois, even in urban areas. Its several hosts, principally lamb's-quarter (*Chenopodium*), favor disturbed soils (Shapiro 1966). It is double-brooded. Extreme dates are April 24 through September 10, but most records appear during the summer months of June through August.

Pyrgus centaurae wyandot (Edwards)
Grizzled skipper

Hesperia wyandot Edwards 1863*a*:21 (type-locality "Long Island [New York]; Washington, D. C.").
Hesperia centaurae: Holland 1931:340.
Pyrgus centaurae wyandot: Klots 1951:215; dos Passos 1964:19 (No. 157b).

Illinois records.—Cook County: Chicago, no date Schlieter, (FMNH *ex* A. L. McElhose collection).

This is "a very old record," according to Wyatt (personal communication). It is probably casual, as Illinois lies somewhat south of the normal range of this subspecies of *centaurae*.

Pyrgus communis (Grote)
Checkered skipper

‡*Hesperia tessellata* Scudder (*nec* Hewitson) 1872:73 (type-locality "Pennsylvania, Maryland, Iowa, Florida, Alabama, Texas, Missouri and California").
Syricthus communis Grote 1872:69 (type-locality "Central Alabama").
Pyrgus tessellata: Worthington 1880:49.
Hesperia communis: Holland 1931:342.
Pyrgus communis: Klots 1951:215; dos Passos 1964:19 (No. 161).

Illinois records.—Map 20.

The checkered skipper, common throughout Illinois, is a characteristic species of autumn; early season records are few. There is considerable color variation. Records are available from March 22 through November 14, but the species reaches its greatest abundance during late August and throughout September.

Erynnis icelus (Scudder & Burgess)
Dreamy dusky wing

Nisoniades icelus Scudder & Burgess 1870:288 (type-locality "New England").
Thanaos icelus: Worthington 1880:49; Holland 1931: 350.
Erynnis icelus: Klots 1951:222; dos Passos 1964:20 (No. 163).

Illinois records.—Cook County: Palos Park, May 22, 1927, May 30, 1931, Herz (FMNH); Palos Park, May 31, 1914, Gerhard (FMNH); Palos Park, May 7, 1922, May 30, 1923, Beer (INHS). Lake County: "Beach" (Waukegan Dunes), May 21, 1922, Wyatt (FMNH). McHenry County: Algonquin, June 8, June 11, Nason (INHS). Madison County: Alton, April, 1948, Lauck (P. S. Remington 1948).

E. icelus is superficially similar to *Erynnis brizo,* but the genitalia offer abundant distinct characters. Like *brizo,* it is a single-brooded spring species, but appears somewhat later in the season. It appears to be less common than *brizo*; we have numerous records of the latter, but the above are the only Illinois records of the present species. We have not seen the material on which the Alton record is based and suggest that there may be a slight question as to its correctness since the locality is widely disjunct from the remainder of the known range of *icelus* in Illinois. It may, however, occur in the intervening territory, having been overlooked or confused with the following species.

Erynnis brizo (Boisduval & Le Conte)
Sleepy dusky wing

Thanaos brizo Boisdual & Le Conte 1834: Plate 66 (type-locality "North America").
Thanaos brizo: Worthington 1880:49; Holland 1931: 349.
Erynnis brizo: Klots 1951:222; dos Passos 1964:20 (No. 164).

Illinois records.—Map 21.

E. brizo is rather common, probably throughout Illinois, although available records are widely scattered. It is a single-brooded, early spring butterfly of woodland roads and clearings. It has been recorded as early as March 30 and as late as May 18.

Erynnis baptisiae (Forbes)
Wild indigo dusky wing

Thanaos baptisiae Forbes 1936:111 (type-locality "Woods Hole, Massachusetts").
Erynnis baptisiae: Klots 1951:227; dos Passos 1964:20 (No. 167).

Illinois records.—Map 22.

This species and *E. lucilius* constitute a pair of nearly indistinguishable but biologically divergent siblings differing almost entirely in food-plant selection. Unlike the other species of *Erynnis* in Illinois, these are inseparable by means of genitalic characters. For this reason, it is virtually impossible to separate them with certainty when host plant association is lacking. The species are monophagous, *E. baptisiae* feeding upon *Baptisia* (wild indigo), and *E. lucilius* on *Aquilegia* (columbine). Burns (1964) stated that there are indications of differences in larval morphology. Differentiation of the adults is complicated by the presence in both species of two differing temporal phenotypes.

The older literature is almost wholly unreliable because of authors' failure to separate properly the species comprising this complex. Before the recognition of *baptisiae* as a separate species, it was lumped with *persius* or *lucilius*; most old records of *"E. persius"* from the eastern states, probably including that of Worthington from Illinois, actually refer to *baptisiae*.

E. baptisiae is the dominant member of the complex in Illinois. The existence of *E. lucilius* and *persius* in Illinois has not been confirmed. Only records based on specimens with positive food plant association data have been accepted. H. A. Freeman determined a number of Illinois *Erynnis* as *E. baptisiae* (Fig. 1), and these records have likewise been accepted. *E. baptisiae* is probably statewide in distribution and common, although authentic records are few and widely scattered. The record from Macon County is that of the allotype male from Decatur.

Host-associated material is greatly needed in order to determine accurately the range of *baptisiae* in Illinois, as well as to confirm the suspected presence of *lucilius*. *E. baptisiae* is multivoltine, with dates of capture in Illinois ranging from April 17 through September 10, and develops differing spring and summer phenotypes as above indicated.

Burns (1964) presented a monographic treatment of the genus *Erynnis*. The *persius* species group received special attention.

Erynnis zarucco (Lucas)
Zarucco dusky wing

Thanaos zarucco Lucas 1857:641 (type-locality "Cuba").
Thanaos terentius: Holland 1931:354.
Erynnis zarucco: Klots 1951:227; dos Passos 1964:20 (No. 168).

Illinois records.—Jackson County: Big Muddy Game Refuge, October 3, 1971, Nielsen, determined by R. R. Irwin (INHS).

The occurrence of *E. zarucco* in Illinois, previously considered probable, was confirmed by the above record, which represents a northward extension of its range in the Mississippi Valley. According to Burns (1964:167) *E. zarucco* is sporadic north of Tennessee, and southern Illinois is probably the northern limit of its range.

Erynnis martialis (Scudder)
Mottled dusky wing

Nisoniades martialis Scudder 1869:335 (type-locality "New Jefferson and Dallas County, Iowa").
Thanaos martialis: Worthington 1880:49; Holland 1931:352.
Erynnis martialis: Klots 1951:223; dos Passos 1964:20 (No. 169).

Illinois records.—Map 23.

This easily recognizable species appears to be scarce but statewide in distribution. There are two broods with dates of capture from May 3 through August 21. According to Burns (1964), *E. martialis* exhibits two temporal phenotypes. The host plant is *Ceanothus americanus* (New Jersey tea) (Burns, *loc. cit.*).

Erynnis horatius (Scudder & Burgess)
Horace's dusky wing

Nisoniades horatius Scudder & Burgess 1870:301 (type-locality "New England, Texas, Massachusetts").
Thanaos horatius: Holland 1931:353.
Erynnis horatius: Klots 1951:223; dos Passos 1964:21 (No. 173).

Illinois records.—Map 24.

Although *horatius* is widespread in Illinois, and probably common, our records reflect only one or two captures in each locality from which it has been reported. This indicates that it must have been widely overlooked or confused with other *Erynnis,* chiefly *juvenalis.* Nearly all of the material we studied was taken from July to September. Although the species is double-brooded, we have only two records of spring specimens from Illinois. Burns (1964) stated that *horatius,* like other multivoltine *Erynnis,* develops spring and summer phenotypes. Host plants include various species of *Quercus* (oaks).

Erynnis juvenalis (Fabricius)
Juvenal's dusky wing

Hesperia juvenalis Fabricius 1793:339 (type-locality "America").
Thanaos juvenalis: Worthington 1880:49; Holland 1931:353.
Erynnis juvenalis: Klots 1951:226; dos Passos 1964:21 (No. 174).

Illinois records.—Map 25.

E. juvenalis is generally distributed throughout Illinois and is rather common. All records are from mid-April through early June. Late-season records are unconfirmed and probably represent *horatius,* except for one authentic male from Lee Center, Lee County, October 1, 1934 (INHS, *ex* Emil Beer collection). Since Burns (1964) asserted that *E. juvenalis* is strictly univoltine except at the southern limits of its range, in Florida, this anachronistic record is difficult to explain. Host plants are oaks of various species.

Timochares ruptifasciatus (Plötz)
Timochares skipper

Antigonus ruptifasciata Plötz 1884:27 (type-locality "South America").
Timochares ruptifasciata: Klots 1951:228.
Timochares ruptifasciatus: Holland 1931:356; dos Passos 1964:22 (No. 179).

Illinois records.—Jersey County: Elsah, August 29, 1941, C. L. Remington (P. S. Remington 1956).

The individual was an obvious casual, perhaps windborne.

Staphylus hayhurstii (Edwards)
Southern sooty wing

Hesperia hayhurstii Edwards 1870:22 (type-locality "Missouri").
Pholisora hayhurstii: Worthington 1880:49; Klots 1951:218.
Pholisora hayhursti: Holland 1931:346.
Staphylus mazans hayhurstii: dos Passos 1964:23 (No. 188b).

Illinois records.—Map 26.

This species is apparently absent in the northern counties; it is "scarce" in Perryton Township, Mercer County, at the apparent northern limit of its range in Illinois (PJC) but is more common southward. At Elsah, Jersey County, Remington found two broods. The first, flying from mid-May throughout June, consisted of "considerable numbers," and the second, in late August, was smaller. We separate this species from *S. mazans* (Reakirt) on the advice of H. A. Freeman (personal communication).

Thorybes bathyllus (J. E. Smith)
Southern cloudy wing

Papilio bathyllus J. E. Smith 1797:43 (type-locality "[probably Screven County,] Georgia").
Eudamus bathyllus: Worthington 1880:49.
Thorybes bathyllus: Holland 1931:335; Klots 1951:212; dos Passos 1964:25 (No. 200).

Illinois records.—Map 27.

This skipper is generally distributed throughout the state and is common. It has been recorded from late April through September.

Thorybes pylades (Scudder)
Northern cloudy wing

‡*Eudamus bathyllus* Harris (*nec* J. E. Smith) 1862*b*:312 (type-locality "Massachusetts").
Eudamus pylades Scudder 1870:207 (new name); Worthington 1880:49.
Thorybes pylades: Holland 1931:335; Klots 1951:212; dos Passos 1964:25 (No. 201).

Illinois records.—Map 28.

This species is distributed throughout Illinois. It

is more abundant than *bathyllus* and has an earlier flight period. The extreme dates of capture are May 14 and July 29.

Achalarus lyciades (Geyer)
Hoary edge

‡*Papilio lycidas* J. E. Smith (*nec* Cramer) 1797:89 (type-locality "[probably Screven County,] Georgia").
Proteides lyciades Geyer 1832: Plate 599 (type-locality "Bahia").
Eudamus lycidas: Worthington 1880:49.
Achalarus lycidas: Holland 1931:336.
Achalarus lyciades: Klots 1951:210; dos Passos 1964:26 (No. 207).

Illinois records.—Map 29.

Records of the hoary edge are widely scattered throughout Illinois, indicating statewide distribution. *A. lyciades* is single-brooded and comparatively scarce in the northern portion of the state, double-brooded and more common southward. The earliest and latest dates are May 11 and September 1. At Elsah, Jersey County, the first brood flies from mid-May to mid-June and the second, fewer in numbers, in late August (CLR). The second brood is absent in the north. The skipper may be overlooked because of its resemblance on the wing to the more common *Epargyreus clarus.*

Autochton cellus (Boisduval & Le Conte)
Golden banded skipper

Eudamus cellus Boisduval & Le Conte 1834: Plate 73 (type-locality restricted to "Jacksonborough, Screven County, Georgia" by Clark 1936*b*:7).
Rhabdoides cellus: Holland 1931:338.
Autochton cellus: Klots 1951:211; dos Passos 1964:26 (No. 211).

Illinois records.—Union County: Pine Hills, July 26, 1966 (Fig. 1), August 21, 1966, September 1, 1966, Downey (INHS, SIU).

The establishment of this scarce butterfly at the locality cited is indicated by the fact that Downey encountered it there three times in one season. It may occur elsewhere in southern Illinois.

Epargyreus clarus (Cramer)
Silver spotted skipper

‡*Papilio tityrus* Fabricius (*nec* Poda) 1775:532 (type-locality restricted to "Dayton, Rockingham County, Virginia" by Dixon 1955:7).
Papilio clarus Cramer 1775(1):66 (type-locality restricted to "Dayton, Rockingham County, Virginia" by Dixon, *loc. cit.*).
Eudamus tityrus: Worthington 1880:49.
Epargyreus tityrus: Holland 1931:329.
Epargyreus clarus: Klots 1951:206; dos Passos 1964:29 (No. 236).

Illinois records.—Map 30.

This large, strong-flying and robust skipper is common throughout Illinois. Records are from April 6 through September 28. It is at least double-brooded in most of the state.

PAPILIONIDAE

Battus philenor (Linnaeus)
Pipe vine swallowtail

Papilio philenor Linnaeus 1771:535 (type-locality "America"); Worthington 1880:47; Holland 1931:312; Klots 1951:179.
Battus philenor: dos Passos 1964:33 (No. 246).

Illinois records.—Map 31.

The pipe vine swallowtail is found throughout the state and is locally common. There are two broods. A spring generation flies from April 24 (Union County) through May 31. The summer brood, consisting of individuals that are larger than those in the spring brood, has been recorded from July 2 through September 23.

Papilio polyxenes asterius Stoll
Black or parsnip swallowtail

Papilio asterius Stoll 1782(4):194 (type-locality "New York, Virginia, Carolina").
Papilio asterias: Worthington 1880:47.
Papilio polyxenes asterius: Holland 1931:314; Klots 1951:172; dos Passos 1964:34 (No. 248a).

Illinois records.—Map 32.

The black swallowtail is the most common member of its family in Illinois, and it is generally distributed. Like other swallowtails, its spring brood consists of smaller, brighter individuals than the later generations. The earliest date is April 3 and the latest October 14. There is a record from Evanston, Cook County, February 18, 1896, Snyder (FMNH) but this is probably the result of premature emergence, perhaps from a pupa protected by a heated structure or influenced by abnormal weather.

Papilio cresphontes Cramer
Giant swallowtail

Papilio cresphontes Cramer 1777(2):106 (type-locality "New York, Jamaica, South Carolina"); Worthington 1880:47; Holland 1931:317; Klots 1951:173; dos Passos 1964:35 (No. 256).

Illinois records.—Map 33.

The largest of our butterflies, *P. cresphontes* has been recorded from localities in all parts of Illinois but it is sporadic in occurrence and never common. Its broods conform to those of other swallowtails in Illinois, the first brood being smaller than the second both in size and number of individuals. The spring generation flies from May 14 (earliest date on record) through June and the summer brood appears near the end of July. The latest date of capture of this species is August 24, but the butterfly is probably on the wing into September in the southern counties. The giant swallowtail is often seen but less frequently captured because of its high, powerful flight. It tends to follow flight paths, but seldom rests except to feed upon flowers.

Papilio glaucus Linnaeus
Tiger swallowtail

Papilio glaucus Linnaeus 1764:190 (type-locali

"America"); Klots 1951:175; dos Passos 1964:36 (No. 262).

Papilio turnus: Worthington 1880:47; Holland 1931: 318.

Illinois records.—Map 34.

This familiar and beautiful insect is moderately common and is generally distributed throughout the state. Early-season individuals, like those of other species of the genus, are on the average smaller in size than later specimens. Yellow females are uncommon to rare. We have seen only five specimens from Cook County, two of which were taken by Irwin near Willow Springs on August 8 and August 12, 1966 (INHS). There are seven records of yellow females from the Streator area in La Salle County (INHS, RRI) and only four other state records. Ellis regarded yellow females as "very rare" at Danville, Vermilion County. Only one specimen was taken there during a period of some 25 years (TE). Remington, however, found the yellow females "quite frequent" at Elsah, Jersey County (CLR). An accurate picture of the ratio of yellow females to dark ones cannot be determined from records obtained during this study, however, because it is not known whether or not all collaborators segregated their records of the yellow females. Dates on record range from April 7 through September 12.

Papilio troilus Linnaeus
Spicebush swallowtail

Papilio troilus Linnaeus 1758:459 (type-locality suggested as "lower Delaware River" by Brown 1968: 81); Worthington 1880:47; Holland 1931:320; Klots 1951:178; dos Passos 1964:36 (No. 267).

Illinois records.—Map 35.

Although there are no records from the northwestern counties, *troilus* probably occurs throughout Illinois. It is common in the southern half of the state but seems to be less common or rare northward. Although there are few records from Cook County, and most of them are old, we have found the species numerous at nearby Hessville, Indiana. At Streator, La Salle County, it was common only in 1955, having been found only once previously and not subsequently during more than 30 years of collecting. This butterfly is double-brooded, and the extreme dates of collection are April 2 and October 5.

Eurytides marcellus (Cramer)
Zebra swallowtail

Papilio marcellus Cramer 1777(2):4 (type-locality "Virginia"); Klots 1951:179.
Papilio ajax: Worthington 1880:47; Holland 1931:321.
Graphium marcellus: dos Passos 1964:37 (No. 269).

Illinois records.—Map 36.

E. marcellus is locally common to abundant, occurring in close association with its host plant, pawpaw (*Asimina triloba*). Individuals of the large, dark, summer brood (*lecontei*) are more apt to stray from the vicinity of the plants than those of the smaller, lighter, and brighter spring brood. Records are lacking from northwestern Illinois and from the northernmost tier of counties (except Lake County). Jones & Fuller (1955) indicate the absence of *Asimina* from this general area, thus predicating similar absence of the butterfly. Their distribution map of *Asimina* is nearly identical to that of *marcellus*, as is to be expected from the close host-plant association. As indicated by Klots (1951), there is considerable overlapping of broods in this species, but in general the individuals of the early spring brood are smaller and lighter, and have shorter tails, than the later butterflies. The earliest date for this brood is April 2 in southern Illinois (Union County), and for the northern area it is April 20 (La Salle County). The latest date of capture is September 20 (Greene County). In the generic placement of this species, we follow Munroe (1961).

PIERIDAE

Pieris protodice Boisduval & Le Conte
Checkered white

Pieris protodice Boisduval & Le Conte 1829:45 (type-locality "New York and Connecticut"); Worthington 1880:47; Holland 1931:280; Klots 1951:200; dos Passos 1964:39 (No. 277).

Illinois records.—Map 37.

The checkered white is fairly common throughout Illinois, notwithstanding the probable harmful effect of competition with *Pieris rapae*. Early reports of the state entomologist of Illinois (Thomas 1878, 1880, 1881) include both *protodice* and *oleracea* among insects of economic importance as pests of cabbage and other Cruciferae. They could scarcely be so ranked today, *protodice* having been almost entirely displaced from this status by *rapae*. Earliest and latest dates of capture of *protodice* in Illinois are March 7 and October 5, respectively. Maximum numbers are reached in late August and early September.

Pieris napi oleracea (Harris)
Mustard white

Pontia oleracea Harris 1829:402 (type-locality "New Hampshire and Massachusetts").
Pieris oleracea: Worthington 1880:47.
Pieris napi oleracea-hiemalis: Holland 1931:281.
Pieris napi oleracea: Klots 1951:201; dos Passos 1964: 39 (No. 278d).

This species formerly occurred in northern Illinois but is now apparently extinct in the state. We have not seen any authentic specimens of Illinois *oleracea*, but the statements of French (1878), Thomas (1880) and Middleton (1881) leave no doubt of its presence. Thomas said, "This species is found only in northern latitudes, its range in this stage not extending even to the central portion so far as I am aware," while the words of Middleton were that it was then "found only in the northern part of the state." The species was not listed by Hart (1903). The distribution map of *oleracea* in Scudder (1889) shows the northern tier of counties lying within its range, whereas Blatchley (1891) listed it as found sparingly in northern Indiana. The present range of *napi*, and its southern limits, were discussed by Hovanitz (1962) and Mather (1964). *E. oleracea* now reaches southern Wisconsin and southern lower Michigan.

There are four specimens of *oleracea* in the INHS collection from the Selim H. Peabody collection. They

lack data, but it is possible that they are Illinois specimens.

The usual explanation for the range restriction of *oleracea* is the harmful competition imposed upon it by *P. rapae*. This has without doubt played an important role in its decline. However, as pointed out by Hovanitz (*loc. cit.*), the reduction of forest cover has probably been of equal if not greater importance in this respect, by virtually eliminating favorable habitats from the portion of the state formerly occupied by the species. Whatever the cause, there seems little question that *oleracea* has been extirpated from the Illinois fauna, although there is a possibility that it might occur casually in the extreme northeastern part of the state.

Pieris rapae (Linnaeus)
European cabbage butterfly

Papilio rapae Linnaeus 1758:468 (type-locality restricted to "Sweden" by Verity & Querci 1923:20).
Pieris rapae: Worthington 1880:47; Holland 1931:282; Klots 1951:200; dos Passos 1964:40 (No. 280).

Illinois records.—Map 38.

This butterfly is abundant throughout Illinois, particularly in cultivated areas. Early spring individuals are smaller than those in later broods and have less heavy dark markings; these are sometimes reduced to a mere apical black spot, but we have never seen a specimen from Illinois in which the dark markings were entirely absent.

P. rapae is an introduced European species, as its common name implies, and is known to everyone as an exceedingly destructive pest on cabbage and other crucifers. It is foremost among all butterflies in economic importance. It is believed to have reached Illinois about 1876, and the first definite record of its capture appears to have been at "Maplewood, west of Chicago" in September, 1877, by Worthington (French 1878; Thomas 1880), although Scudder (1889) reported unauthenticated records of the insect in Illinois as early as 1874. Within a few years it had occupied the entire state, to the detriment not only of its hosts but of the native species of *Pieris: protodice* and *napi oleracea*.

The earliest and latest dates for *rapae* in Illinois are March 27 and October 6.

Colias eurytheme Boisduval
Alfalfa butterfly, orange sulphur

Colias eurytheme Boisduval 1852:286 (type-locality "California"); Worthington 1880:47; Holland 1931:297; Klots 1951:183; dos Passos 1964:41 (No. 286).

Illinois records.—Map 39.

Abundant throughout Illinois, *eurytheme* is probably our commonest butterfly. Despite a great deal of study in recent years, the relationship between this species and *philodice* is unclear. We have assigned all specimens having any orange to *eurytheme*, and all clear yellow specimens to *philodice;* Klots (1951) indicated the reliability of this procedure with respect to eastern-area material. As he pointed out, however, white females of the two species are not always distinguishable from each other with certainty; the spots in the borde of the fore wing are usually somewhat larger in *eury theme*.

Individual variants are frequently encountered, nea ly all of them females. One consistently occurrin variation has the upper surface of the fore wings whit sometimes with a buff suffusion, whereas the hind win are a light yellow or greenish yellow. White femal occasionally have this buff suffusion on both wings wit out any yellow or orange. The dark borders of t fore wings are occasionally very wide, accompanied b an enlargement of the basal dark area, so that the lig area of the fore wings is much restricted. Such a whi female was taken at Streator, La Salle County, Septe ber 26, 1946, Irwin (INHS). In this individual t hind wings are dark greenish yellow. A female tak at Highland Park, Lake County, in August, 1961, May (FMNH) has the primaries and secondaries the left side yellow with those on the right side whi Wyatt recorded a similar specimen taken by Bristol Elgin, Kane County (AKW). A number of melan aberrations of varying degree and of both sexes ha been taken in Illinois (FMNH).

The earliest date of capture of *eurytheme* in Illin is March 27. The latest date is December 7, at Arli ton Heights, Cook County, McElhose (FMNH). T is the latest recorded date of flight for any butterfly Illinois. On the day previous to this date, Irwin served the species on the wing at Streator, La Sa County.

Colias philodice Godart
Common or clouded sulphur

Colias philodice Godart 1819:100 (type-locality "No America, particularly in Virginia"); Worthing 1880:47; Holland 1931:293; Klots 1951:185; Passos 1964:41 (No. 287).

Illinois records.—Map 40.

The clouded sulphur is common and generally tributed throughout Illinois, although it is less ab dant than *eurytheme*. Like that species, *philodice* t to produce frequent individual variants, especiall the female sex. Some have white fore wings and low or yellowish hind wings, analogous to the varia in *eurytheme*. Others may have the light spots in fore-wing border nearly or wholly obsolete; these been found in both the white and yellow phases of female. Still others are more or less unique in ma of variation. An example is a female taken at Stre La Salle County, September 18, 1960, Irwin (IN In this individual the black of the borders is proje inwardly along the veins, especially those of the wings, giving it an odd appearance somewhat re bling *Colias cesonia*. It was regarded by F. M. B as a possible hybrid with *cesonia* but more like mere mutant *philodice*. Another unusual female taken at Streator, La Salle County, 1942, Pl (INHS). The dark borders of its hind wing a wide and heavy as those of the fore wings, but wi white spots or the incursion of white ground color ing it a superficial appearance suggesting *Colias m* Edwards. We list these variants to illustrate the ty divergence which may be anticipated in the sp Records are from April 10 through November 18. *eurytheme* and *philodice* are multivoltine; the au

broods usually emerge in numbers about the middle of September, and, as indicated by the late dates of capture, fly until the end of the season, very late in some years.

Colias cesonia (Stoll)
Dog face

Papilio cesonia Stoll "1791" [1790]:176 (type-locality "Georgia").
Colias caesonia: Worthington 1880:47.
Zerene caesonia: Holland 1931:292.
Colias cesonia: Klots 1951:189; dos Passos 1964:44 (No. 299).
Colias caesonia, gen. aut. rosa M'Neill 1889:44 (type-locality "3 mi. E Moline, Rock Island County, Illinois").

Illinois records.—Map 41.

Records of this species are from throughout Illinois. t is common southward, rarer in the northern counties. Occasionally considerable numbers of the species are ound in more northern localities, especially at the Waukegan Dunes (Illinois Beach State Park), Lake County. nyder (1896) recorded *cesonia* as "abundant" at Evanston, Lake County, in 1895. *C. cesonia* is probbly an immigrant in most of northern Illinois, but a reeding resident further south and no doubt occasionlly in the north as well. Irwin took two newly emerged nales at Cornell, Livingston County, on August 16, 966 (INHS); the dog face is consistently uncommon o rare in that area. The cold weather form *rosa*, deribed from Illinois, is the predominant autumn form f the species. Extreme dates on record are April 5 nd October 15, and most records have been made durng late summer and autumn (*rosa*).

The flight of *cesonia* is fast and strong, and this pecies seldom rests other than when visiting flowers.

Phoebis sennae eubule (Linnaeus)
Cloudless sulphur

apilio eubule Linnaeus 1767:764 (type-locality "Carolina").
allidryas eubule: Worthington 1880:47; Holland 1931:289.
hoebis sennae eubule: Klots 1951:190; dos Passos 1964:45 (No. 302).

Illinois records.—Map 42.

Although there are no records for the northernmost er of counties, the cloudless sulphur probably occurs least sporadically in all parts of Illinois. It is genally rare in the northern portion of the state but ocsionally appears in some numbers, usually in late sumer or autumn and probably as the result of migratory ovements. Irwin observed such movements at Streator, a Salle County, August 12 through 14, 1946, and again ugust 11 and 12, 1953. *P. s. eubule* appeared in great umbers at Ramsey, Fayette County, where L. S. Phlps saw or captured a total of 58 specimens on August and 30, 1953 (LSP). There was a similarly impresve appearance of the insect at Urbana, Champaign ounty, in August 1925 when 28 specimens were taken T. H. Frison (INHS). *P. s. eubule* is common to undant in southern Illinois. C. L. Remington reorted it in "great numbers" at Elsah, Jersey County, late July through October (CLR). On August 31, 1969, Irwin observed many individuals along Illinois Highway 3 between East St. Louis and the Pine Hills, Union County.

All Illinois *sennae* are probably of the subspecies *eubule*. C. L. Remington (1943) listed two newly emerged examples of the mainland tropical subspecies *P. s. marcellina* (Cramer) from Elsah, Jersey County, but since Klots (1951) regarded the subspecific classification of *sennae* as "extremely complex and largely statistical," we believe it best to consider these specimens as only similar to *marcellina*. Both French (1879) and Worthington (1880) listed *sennae* and *eubule* separately. Exactly what they were calling by each name cannot, of course, now be determined with certainty, although French (*loc. cit.*) characterized *sennae* as having the "ground color pale dirty yellow, marks heavier," instead of "clear pale yellow" as in *eubule*. Inclusive dates for *eubule* in Illinois are April 19 through November with most records being in August and September.

Phoebis philea (Johansson)
Orange barred sulphur

Papilio philea Johansson 1763:404 (type-locality "West Indies").
Callidryas philea: Worthington 1880:47; Holland 1931:289.
Phoebis philea: Klots 1951:191; dos Passos 1964:45 (No. 303).

Illinois records.—Cook County: presumably Evanston or vicinity, 18/0 or before (Riley 1870); Chicago (Humbolt Park), August 10, 1937, Sasko (VGS). We have seen the latter specimen, a male, in the Sasko collection. *P. philea* can only be regarded as casual in Illinois. In view of the foregoing records, it may be expected anywhere in the state, although probability would favor its occurrence in the extreme southern counties.

Eurema mexicana (Boisduval)
Mexican sulphur

Terias mexicana Boisduval 1836:655 (type-locality "Mexico").
Eurema mexicana: Holland 1931:301; Klots 1951:196; dos Passos 1964:47 (No. 312).

Illinois records.—Champaign County: Champaign, October 18–19, 1911, Frison (Frison 1919). Cook County: Chicago, October 9, 1904, Beer (INHS); Riverside, October 13, 1910, Mares (INHS) (Fig. 2). Du Page County: Ingalton, October 13, 1911, Mares (INHS). Jersey County: Elsah (campus of Principia College), fall 1940, C. L. Remington (CLR). Kane County: Elgin, September 18, 1925, Bristol (AKW).

This is a species of rare appearance in Illinois in autumn, probably as the result of migratory movements. Frison (1919) described such an occurrence at Champaign, Champaign County, when 14 specimens were taken and many more seen "flying in flocks." A specimen of *mexicana* in the INHS collection taken by Frison at Champaign, dated August 18, 1911, is believed to be one of those discussed in his paper, but with an error in labeling, as he stated that none had been observed prior to the October 1911 migration. The specimen

taken by Mares at Ingalton, Du Page County, on October 13 of the same year may have been a member of the same migration. Apparently such occurrences of *mexicana* in Illinois are sporadic and irregular.

There are also two records of this butterfly from Hessville, Lake County, Indiana, both at the same time of year as most of those from Illinois: October 16, 1904, and October 7, 1917, Wyatt (FMNH).

Eurema lisa (Boisduval & Le Conte)
Little sulphur

Xanthidia lisa Boisduval & Le Conte 1829:53 (type-locality "United States").
Terias lisa: Worthington 1880:47.
Eurema lisa: Holland 1931:302; Klots 1951:198; dos Passos 1964:47 (No. 315).

Illinois records.—Map 43.

The little sulphur is found throughout Illinois and is common. Light yellow to white females are frequently found. Earliest and latest dates on record are April 24 and October 23, and the species is most numerous from late July through early September.

Eurema nicippe (Cramer)
Sleepy orange

Papilio nicippe Cramer 1780(3):31 (type-locality "Virginia").
Terias nicippe: Worthington 1880:47.
Eurema nicippe: Holland 1931:301; Klots 1951:197; dos Passos 1964:47 (No. 319).

Illinois records.—Map 44.

We have records of *nicippe* from throughout Illinois except the extreme northwestern counties, where, however, it probably also occurs. It is rare in the Chicago area, where there is only one recent record. Elsewhere in northern Illinois it is intensely local but often abundant where it is found. It is probably commoner and more widespread in the southern half of the state; Holland (1931) spoke of its abundance there. In northern Livingston County, just south of Streator along the Vermilion River, it occupies a locality only a few acres in extent, where it has fluctuated in numbers from extreme abundance (1943–1954) through a decline (1955–1958) and period of apparent absence (1959–1962) to reappearance in 1963 and a gradual increase since then. Similar restricted habitats probably occur elsewhere in northern Illinois, where the host plant wild senna (*Cassia*) occurs. Its decline at the Streator locality was probably attributable to the rarity of its host; the plant was not seen during the period the butterfly was not present.

Of the thousands of *nicippe* we have seen and captured, only one has been of the rare yellow form *flava,* a male taken at the above locality south of Streator in Livingston County, September 10, 1963, Irwin (INHS). There is another form with the underside reddish instead of the normal yellow, which is unknown to us from the state. A few dwarfs of both sexes have been taken.

There are probably three broods, with the third emerging in mid-August and flying through September (Streator) being the largest. The earliest and latest records are April 15 (Evanston, Cook County) and early November (Elsah, Jersey County).

Nathalis iole Boisduval
Dainty sulphur

Nathalis iole Boisduval 1836:589 (type-locality "Mexico"): Worthington 1880:47; Holland 1931:283; Klots 1951:199; dos Passos 1964:48 (No. 320).

Illinois records.—Map 45.

This tiny pierid is found throughout Illinois. It varies in numbers from season to season; in some years such as 1931 and 1944, it was very abundant and in other years it has been completely absent. It is rare in Cook County, where the only records are as follows: Chicago, October 4, 1931, 10 specimens, Wyatt and Lustig (FMNH); Chicago, November 13, 1931, Weed (FMNH); locality and date not specified, two specimens, Leuschner (RL). Frison (INHS) took 51 specimens at Havana, Mason County, October 7, 1931. The earliest date on record is July 4 and the latest is November 13. Most records are from mid-August through mid-October.

Anthocharis midea (Hübner)
Falcate orange tip

Mancipium vorax midea Hübner "1806" [1809]: Pl. 142 (type-locality restricted to "Wilmington Island near Savannah, Georgia" by dos Passos & Klots 1969:6 by designation of neotype).
Anthocaris genutia: Worthington 1880:47; Klots 1951:181.
Euchloë genutia: Holland 1931:287.
Anthocaris midea: dos Passos 1964:49 (No. 325).

Illinois records.—Map 46.

Apparently locally common to abundant in spring in southern Illinois, *A. midea* is rare or absent north of the approximate latitude of East St. Louis. The northernmost record was in Putnam County, May 1939, Glenn (MOG). Nielsen took 14 ♂♂ and 12 ♀ at Wolf Lake Swamp, Union County, April 24, 19 and reported that he saw "a thousand or more" (GM The species was reported as common in open woo mid-March to mid-May, at Elsah, Jersey Coun (CLR). It is single-brooded and appears from n March through May 14.

Cowan (1969) pointed out that the generic na is properly spelled as we have indicated. The Illi population may be referable to the recently descri subspecies *annickae* dos Passos and Klots (*loc. cit.*).

Euchloë olympia (Edwards)
Olympia

Anthocaris olympia Edwards "1871" [1872]:266 (t locality "Coalburgh, West Virginia; Dallas, Texa Worthington 1880:47.
Euchloë olympia: Holland 1931:285; Klots 1951: dos Passos 1964:50 (No. 329).

Illinois records.—Bureau County: probably Township, G. M. Dodge (Edwards 1884). Cook County: Chicago, May 13, 1917, Wyatt (FMNH). Jer County: Elsah, "local and rare" (CLR). Lake County: Waukegan Dunes (Illinois Beach State Park) 2), well established, common to abundant; many ords, May 10 through May 28.

E. olympia probably occurs locally elsewhere in

ois but may be overlooked. It strongly resembles *Pieris apae* in flight; for this reason, a sight record from Peru, La Salle County, cannot be accepted. It is single-brooded, with a short flight period.

RIODINIDAE

Calephelis muticum McAlpine
Swamp metalmark

Calephelis muticum McAlpine 1937:43 (type-locality "Willis, Washtenaw County, Michigan").
Lephelisca muticum: Klots 1951:123; dos Passos 1964: 51 (No. 343).

Illinois records.—Kane County: Elgin, July 12, 930, July 19, 1930, Herz (FMNH); Elgin, July 12, 939, (INHS) (Fig. 2); Elgin, July 31, 1920, July 19, 931, Bristol (AKW).

Scudder (1889:790) recorded *Calephelis borealis* rom the "Township of Ohio" in Bureau County, G. M. Dodge. The record probably refers to *muticum,* which as undistinguished from *borealis* at that time, but cudder's date of May 7 is inconsistent with the known ight periods of both *muticum* and *borealis*. Records y Worthington (1880) and Holland (1931) of *borelis* from Illinois are probably traceable to the same ource. There is one brood, flying in late July as above. ristol (personal communication) reported the larvae n swamp thistle in June.

Specimens from the "Chicago, Illinois . . . area" tak-n by Wyatt are mentioned in the original description. othing further is known of these specimens; the local-y citation may refer to Elgin, which lies within the reater metropolitan area.

The generic name *Calephelis* has recently been vali-ated, and *Lephelisca* suppressed, by the International ommission on Zoological Nomenclature (McAlpine 971).

LYCAENIDAE

Harkenclenus titus (Fabricius)
Coral hairstreak

Hesperia titus Fabricius 1793:297 (type-locality *"in Anglia"*).
Thecla titus: Worthington 1880:48; Holland 1931:242.
Strymon titus: Klots 1951:134.
Harkenclenus titus: dos Passos 1970:28 (No. 355).

Illinois records.—Map 47.

It is likely that *titus* occurs throughout Illinois. It is ther common. *H. titus* is single-brooded, with dates capture between June 2 and August 22.

Satyrium liparops strigosa (Harris)
Striped hairstreak

Thecla strigosa Harris 1862*a*:101 (type-locality "Blue Hill, Massachusetts"); Worthington 1880:48.
Thecla liparops: Holland 1931:235.
Strymon liparops strigosus: Klots 1951:138.
Satyrium liparops strigosa: dos Passos 1970:29 (No. 361b).

Illinois records.—Map 48.

S. liparops strigosa is widespread in Illinois, but apparently local and usually occurring only as single individuals. Occasionally one finds it in greater numbers, as in the forest preserves near Willow Springs, Cook County. Even at such times and places, however, it never reaches the abundance of some of its congeners. As an example of the nature of its occurrence, in August, 1966, Irwin took one specimen of *strigosa* during each of four visits to the above locality, on the 5th, 6th, 9th, and 12th. There is one brood, with dates of capture from June 10 through August 12, but the insect is seldom encountered after the end of July.

Satyrium calanus falacer (Godart)
Banded hairstreak

Polyommatus falacer Godart "1819" [1824]:633 (type-locality "vicinity of Philadelphia, North America").
Thecla calanus: Worthington 1880:48; Holland 1931: 234.
Strymon falacer: Klots 1951:137.
Satyrium calanus falacer: dos Passos 1970:29 (No. 363b).

Illinois records.—Map 49.

Recorded from throughout the state, this and *H. titus* are our most common and widespread hairstreaks. *S. calanus* favors much the same habitat as *S. edwardsii* and is frequently found in association with it. This hairstreak may be confused with *edwardsii* and also with *S. caryaevorus,* from which it may not always be distinguished by superficial characters. *S. calanus* is apparently also single-brooded but has a longer flight season than *edwardsii*. We have records from May 24 through August 9.

Lafontaine (1969, 1970) has recently described *Satyrium boreale,* a new hairstreak very close to *falacer* but apparently founded upon good superficial as well as genitalic differences. Inasmuch as this description appeared during an advanced stage of the preparation of the present list, it was not feasible to re-examine all Illinois *falacer* to determine the possible occurrence of the new species in the state. Lafontaine (*loc. cit.*) recorded it from Michigan, Ohio, and Pennsylvania, and its presence in Illinois is a distinct possibility.

Satyrium caryaevorus (McDunnough)
Hickory hairstreak

Strymon caryaevorus McDunnough 1942:1 (type-locality "Merivale, Ontario"); Klots 1951:137.
Satyrium caryaevorus: dos Passos 1970:29 (No. 364).

Illinois records.—Adams County: Quincy, July 1899, Poling, determined by Orley R. Taylor, Jr. (USNM). Jackson County: Carbondale, June 9, 1963, determined by J. C. Downey (JCD).

Downey (1966) listed *caryaevorus* only from Cook County. Subsequent genitalic study of the material on which this record was based has proven it to be *S. calanus falacer.* The above records, not listed by Downey (*loc. cit.*), are the only authenticated ones of *caryaevorus* from Illinois, but it may be expected to occur anywhere in the state. *S. caryaevorus* is often virtually indistinguishable from *falacer* by superficial characters, so that genitalic examination is essential for correct de-

termination. The species is single-brooded, temporally and spatially associated with the other commoner species of the genus. As the name implies, it is a hickory feeder.

Satyrium edwardsii (Saunders)
Edwards' hairstreak

Thecla edwardsii Saunders 1869:98 (type-locality restricted to "Queenstown, Ontario" by Michener & dos Passos 1942:4 by designation of neotype); Worthington 1880:48.
Thecla edwardsi: Holland 1931:234.
Strymon edwardsii: Klots 1951:136.
Satyrium edwardsii: dos Passos 1970:29 (No. 365).

Illinois records.—Map 50.

S. edwardsii is locally common to abundant in association with the host plant, oak (*Quercus*). Confusion with *S. calanus falacer* is possible. This is a single-brooded, midsummer butterfly, with earliest and latest dates of observation June 12 and August 1.

In Illinois, *edwardsii* appears to be limited chiefly to the northern half of the state, principally the northeastern portion. It has been recorded only once from Streator, La Salle County, during 30 years of collecting there, and the work of Downey and his associates in southern Illinois did not disclose its presence. Thomas Taylor found it abundant at Mason State Forest, Mason County, where the adults were present on butterfly-weed (*Asclepias tuberosa*).

Satyrium acadica (Edwards)
Acadian hairstreak

Thecla acadica Edwards 1862*a*:55 (type-locality "London, [Ontario]"); Worthington 1880:48; Holland 1931:237.
Strymon acadica: Klots 1951:136.
Satyrium acadica: dos Passos 1970:29 (No. 368).

Illinois records.—Map 51.

Except for an unconfirmed record from Alton in Madison County, all records of *acadica* are from the northeastern counties. It is frequent to common locally, where the host plant, willow (*Salix*) occurs. There is probably one brood; the species has been taken from June 14 through August 22.

Eumaeus atala Poey
Atala

Eumenia atala Poey 1832(1): Plate *Eumenia* + text 3 p. (type-locality "Havana, Cuba").
Eumaeus atala: Holland 1931:223; Klots 1951:132; dos Passos 1970:30 (No. 370).

French (1900:395) recorded this species from Carbondale, Jackson County. Since it seems inconceivable that he could have confused this distinctive species with any other, we do not doubt the accuracy of the record. However, we rely on the usual explanation of such occurrences: that the insect, in some stage of development, may have been transported to Illinois, perhaps on the Illinois Central Railroad, which has a direct line between Carbondale and southern Florida. The butterfly is not a regular part of the Illinois fauna.

Calycopis cecrops (Fabricius)
Red banded hairstreak

Hesperia cecrops Fabricius 1793:270 (type-locality "West Indies").
Thecla poeas: Worthington 1880:48.
Thecla cecrops: Holland 1931:239.
Strymon cecrops: Klots 1951:133.
Calycopis cecrops: dos Passos 1970:30 (No. 379).

Illinois records.—Map 52.

The Cook County record is apparently a casual stray. In southern Illinois, *cecrops* is rare but occurs consistently and likely has local populations.

Callophrys polios (Cook & Watson)
Hoary elfin

Incisalia polios Cook & Watson 1907:202 (type-locality "Lakewood, New Jersey"); Klots 1951:147.
Thecla polios: Holland 1931:227.
Callophrys polios: dos Passos 1970:31 (No. 382).

Illinois records.—Cook County: Chicago, May 1911, Wyatt (FMNH). Lake County: Waukegan Dunes (Illinois Beach State Park) (Fig. 2), many specimens, dates, collectors, and sources.

C. polios is well established and often common to abundant at Illinois Beach State Park in association with its host, bearberry (*Arctostaphylos uva-ursi*). It flies at about the same time as *Euchloe olympia*, the other butterfly virtually endemic to that locality in Illinois but appears somewhat earlier. On May 12, 1951 Leuschner found it "numerous almost beyond comprehension" there (RL). It probably does not reach the level of abundance in every season but does occur consistently and is usually common. The flight is close to the ground, and the butterfly often rests on the food plant. It is single-brooded. The earliest and latest dates of capture are April 25 and May 28, but the flight season is short and in any one year probably does not exceed 2 weeks within this general period.

Callophrys irus (Godart)
Frosted elfin

Polyommatus irus Godart "1819" [1824]:674 (type-locality "America?").
Thecla irus: Worthington 1880:48; Holland 1931:2
Incisalia irus: Klots 1951:148.
Callophrys irus: dos Passos 1970:31 (No. 383).

Illinois records.—Lake County: Beach, May 1922, Liljeblad, determined by J. C. Downey (INH).

The male and female specimens of the above record, the only positively known specimens of *irus* from Illinois, were damaged in a fire at the University of Northern Iowa in March, 1970, while being studied by Downey. A single-brooded, rare, and local species of early spring, *irus* may easily be confused with *I. henrici*. It should be found elsewhere in Illinois. We have records from nearby Lake County, Indiana.

Callophrys henrici (Grote & Robinson)
Henry's elfin

Thecla henrici Grote & Robinson 1867*b*:174 (type-lo

ity "Philadelphia, [Pennsylvania]"); Holland 1931: 226.
ncisalia henrici: Klots 1951:147.
Callophrys henrici: dos Passos 1970:31 (No. 384).

Illinois records.—Map 53.

C. henrici is extremely local in Illinois, but apparntly frequent to common where it does occur. C. L. Remington found it "unusually common" at Elsah, Jersey County (CLR); Glenn has taken it regularly in Putnam County (MOG) (Fig. 2); and Ellis has found numerous near Danville, Vermilion County, flying bout red bud (*Cercis canadensis*) (TE). There is one rood, appearing March 30 through May 9.

The species should be sought around red bud trees n early spring when the trees are in full color. Adults ay be observed pirouetting around the treetops, rest-g on the blossoms, and ovipositing on the young leaves.

Callophrys niphon (Hübner)
Pine elfin

icus niphon Hübner "1818" [1823]: Plate 527 (type-locality "Florida").
hecla niphon: Worthington 1880:48; Holland 1931: 227.
ncisalia niphon: Klots 1951:149.
allophrys niphon: dos Passos 1970:31 (No. 388).

Illinois records.—Jackson County: Giant City, May 5, 1957 (SIU); Carbondale, April 21, 1958, Yates SIU). Pope County: 2 mi. S Herod, April 12, 1968, ouseman (JKB).

In the absence of additional records, it is difficult determine the true distribution and abundance of *phon* in Illinois. It is probably not common in any linois localities, but should be expected to occur roughout the state.

Callophrys gryneus (Hübner)
Olive hairstreak

Papilio damon Stoll (*nec* Denis & Schiffermuller) 1782 (4):208 (type-locality "Virginia").
ycus gryneus Hübner "1816" [1819]:74 (new name).
hecla smilacis: Worthington 1880:48.
hecla gryneus: Holland 1931:231.
itoura gryneus: Klots 1951:141.
allophrys gryneus: dos Passos 1970:32 (No. 394).

Illinois records.—Map 54.

The host of this hairstreak, red cedar (*Juniperus virniana*), is found nearly throughout Illinois, but our cords of the butterfly are not as generally distributed this would indicate; the species is local and may ve been overlooked in many localities. As shown by e distribution map, nearly all of our records are from calities near the Illinois or Mississippi rivers, and *yneus* may not be present in all areas where red cedar curs. *C. gryneus* is double-brooded. The earliest and est dates for the first brood are April 22 and May ; for the second, June 27 and July 19.

Thomas Taylor (personal communication) states at *gryneus* is local but common when found. It flies ar the tops of the cedar trees and if disturbed it rts out from the tree and returns quickly, often to e same perch. The males are particularly inclined to remain near the treetops. Taylor found the species common at Mason State Forest, Mason County, and at Jubilee College State Memorial, Peoria County, and Downey considers the species common in southern Illinois.

Atlides halesus (Cramer)
Great purple hairstreak

Papilio halesus Cramer 1777(2):3 (type-locality "Virginia").
Thecla halesus: Holland 1931:224.
Atlides halesus: Klots 1951:133; dos Passos 1970:33 (No. 408).

Illinois records.—Union County: Pine Hills, September 17, 1966, Persons (INHS).

This hairstreak was attributed to Illinois by Holland, Klots, and other authors, probably on the basis of old published records which we were unable to locate; the above is the only positive Illinois record known to us. The specimen was taken while sweeping for other insects and was severely damaged. *A. halesus* is probably only a rare casual in the extreme south. Shapiro (1966) says *halesus* is not resident north of the range of live oak (*Quercus virginiana*), which lies far to the south of Illinois.

Euristrymon ontario (Edwards)
Northern hairstreak

Thecla ontario Edwards "1868" [1869]:209 (type-locality "Port Stanley, Ontario"); Holland 1931:235.
Strymon ontario: Klots 1951:135.
Euristrymon ontario: dos Passos 1970:34 (No. 412).

Illinois records.—Jackson County: Carbondale, May 22, 1964, May 14, 1965, Downey (JCD). Jersey County: Elsah, May 30, 1941, May 30, 1942, C. L. Remington (CLR).

E. ontario is rare in Illinois but may be expected anywhere in the state. It should not be limited, as implied by Downey (1966) on the basis of the few records, to the southern portion of the state.

Panthiades m-album (Boisduval & Le Conte)
White M hairstreak

Thecla m-album Boisduval & Le Conte 1833:86 (type-locality "Georgia"); Worthington 1880:48; Holland 1931:229.
Strymon m-album: Klots 1951:133.
Panthiades m-album: dos Passos 1970:34 (No. 414).

Illinois records.—Map 55.

This hairstreak (Fig. 2) is widespread but rare and erratic in Illinois.

Strymon melinus humuli (Harris)
Gray hairstreak

Thecla humuli Harris 1841:215 (type-locality "Massachusetts"); Worthington 1880:48.
Thecla melinus: Holland 1931:235.
Strymon melinus: Klots 1951:134; dos Passos 1970:34 (No. 417).

Illinois records.—Map 56.

Although *melinus* occurs throughout Illinois and is abundant in the southern portion of the state, it is uncommon to rare northward. There are few records from Cook County. At Streator, La Salle County, only seven specimens have been taken from 1941 through 1969 (RRI). *S. melinus* is apparently double-brooded, with earliest and latest record dates of April 21 and October 2.

Comparison of Illinois *melinus* with material from other states indicates the need for much study of this rather variable species to determine the validity of the subspecies within the taxon. Pending such investigation we assign all Illinois populations to the subspecies *humuli* (Harris).

Lycaena thoe (Guérin-Méneville)
Bronze copper

Polyommatus thoe Guérin-Méneville 1831: Plate 81 (type-locality "North America").
Chrysophanus thoe: Worthington 1880:48; Holland 1931:248.
Lycaena thoe: Klots 1951:152; dos Passos 1964:60 (No. 433).

Illinois records.—Map 57.

The bronze copper is generally distributed throughout Illinois, and is locally frequent, sometimes common. Although generally regarded as a wet-ground species, we have often found it in drier environments, even on occasion within the limits of cities. The allotype female of the aberration *wyatti* Gunder, in which the dark spots of the fore wings are elongated and coalesce, was taken at Chicago, Cook County, September 15, 1907, by A. K. Wyatt. There are two broods. Extreme dates of capture of *thoe* in Illinois are May 17 and November 3. The second brood, appearing in August, seems to be slightly larger in numbers than the first. It should be sought near its food plant, curly dock (*Rumex crispus* L.).

Lycaena xanthoides dione (Scudder)
Great copper

Chrysophanus dione Scudder 1868*b*:401 (type-locality "Denison and New Jefferson, Iowa"); Worthington 1880:48; Holland 1931:248.
Lycaena xanthoides dione: Klots 1951:154; dos Passos 1964:60 (No. 435b).

Illinois records.—Map 58.

This butterfly (Fig. 2) is common in the northern portion of Illinois but not recorded from the southern third of the state, where it may not occur. Although the species is listed by Worthington and there is a record from Normal, McLean County, in 1873 (INHS), most Illinois records are relatively recent, and there is evidence that *dione* is increasing in numbers and distribution in Illinois. Wyatt regarded it as a newcomer to the Chicago area (AKW). We did not find it at Streator, La Salle County, until 1954, when a very restricted colony was discovered along the Santa Fe railroad tracks just east of the city. Since then, it has spread into the city itself. *L. x. dione* is single-brooded. The earliest date of capture is June 9, and the latest July 30, but the main flight season is from the third week of June through the middle of July.

Lycaena helloides (Boisduval)
Purplish copper

Polyommatus helloides Boisduval 1852:291 (type-locality "San Francisco, California").
Chrysophanus helloides: Holland 1931:249.
Lycaena helloides: Klots 1951:153; dos Passos 1964:61 (No. 440).

Illinois records.—Map 59.

Although all of our records are from the northeastern counties, *L. helloides* undoubtedly occurs throughout at least the northern third of the state. It is unlikely that there is a distributional break in northwestern Illinois; its apparent absence probably reflects the general lack of adequate collecting coverage in the area. *L. helloides* is extremely local but is often common to abundant where found. It occurs frequently in association with *L. thoe*. The species was abundant at Goose Lake Prairie, Grundy County, on July 18, 1970. There were several exceedingly localized colonies, each only a few hundred square yards in extent, in which *helloides* abounded together with *L. thoe*. These colonies were separated by areas in which no *helloides* were to be seen although *thoe* was present everywhere. There is a well established colony at Burnham, Cook County. The southernmost records in Illinois are from Streator, La Salle County, and Beaverville, Iroquois County. At the former locality, only a single example of *helloides* has been taken (October 1, 1950, Irwin, INHS), but Irwin Leeuw (personal communication) found it common at Beaverville in late July, 1970.

The earliest and latest dates for the species in Illinois are May 19 and October 21, but the most records are from late July through September. The butterfly is double-brooded and the second brood, emerging near the end of August, is somewhat the larger in number.

Lycaena phlaeas americana Harris
American copper

Lycaena americana Harris 1862*b*:273 (type-locality "Massachusetts").
Chrysophanus americana: Worthington 1880:48.
Chrysophanus hypophlaeas: Holland 1931:251.
Lycaena phlaeas americana: Klots 1951:151; dos Passos 1964:61 (No. 443a).

Illinois records.—Map 60.

This copper is locally frequent, sometimes common and is generally distributed throughout Illinois. Individual variants, including the aberration *fasciata* (Strecker) are often encountered. The species has been taken from April 27 through October 19.

Individuals tend to be local, and colonies may be found in the same relative spot year after year. They feed on curly dock (*Rumex crispus* L.) often in company with *L. thoe*.

Leptotes marina (Reakirt)
Marine blue

Lycaena marina Reakirt 1868:87 (type-locality "Orizaba and near Vera Cruz, Mexico"); Holland 1931:272.
Leptotes marinus: Klots 1951:158.
Leptotes marina: dos Passos 1964:62 (No. 449).

Illinois records.—Cook County: Forest View, [illegible]

Lyons, August 18, 1933, Mares (INHS) (Fig. 2). Mercer County: Hamlet, September 5, 1953, Conway (Conway 1956).

This species is probably only a rare casual in Illinois.

Hemiargus isola (Reakirt)
Reakirt's blue

Lycaena isola Reakirt 1866*b*:332 (type-locality "near Vera Cruz, Mexico"); Holland 1931:271.
Hemiargus isolus: Klots 1951:159.
Hemiargus isola: dos Passos 1964:63 (No. 453).

Illinois records.—Map 61.

C. L. Remington (1942) discussed *isola* in the Midwest with special reference to Illinois. He indicated that *isola* is a breeding resident of the states east of the Mississippi in which it is found. Although it is apparently rare in these states, this rarity may be illusory rather than actual, since *isola* is widely overlooked where it does occur because of its close resemblance to *Everes comyntas* in the field. Collectors should keep this species in mind, and examine as many apparent "*comyntas*" as possible to locate it.

Lycaeides melissa samuelis Nabokov
Melissa blue, Karner blue

Lycaeides melissa samuelis Nabokov 1943:97 (type-locality "Albany, New York"); Klots 1951:165; dos Passos 1964:64 (No. 455e).
Lycaena scudderii: Worthington 1880:48.
Lycaena scudderi: Holland 1931:263.

The only known Illinois specimens of this species are a male and female in the INHS collection, from the Andreas Bolter collection, labeled only "N. Ill." (Fig. 2). The species was attributed to Illinois by Klots (1951). Nabokov (1949) said that *samuelis* may occur on the "western side of the southern end of Lake Michigan." This may refer to the Waukegan Dunes (Illinois Beach State Park), an area apparently well suited to the occurrence of the species. The Dunes have, however, been very well collected for many years, and we know of no *samuelis* from there in any collection. The host, lupine (*Lupinus perennis*), occurs in "sandy soil, local, Northern Ill." according to Jones & Fuller (1955). If *samuelis* still occurs at all in the state, it must be in very small, intensely localized colonies where the food plant occurs. Such a colony still exists near Hessville, Indiana, occupying an area only a few hundred square yards in size, beyond which *samuelis* very seldom strays. Shapiro (1966) regarded this as the most local butterfly of the northeastern states. Downey (1966) also discussed the occurrence of *samuelis* in Illinois. This is another species which may have become extinct in Illinois since the time of Worthington and Bolter, as a possible result of ecological changes.

Everes comyntas (Godart)
Eastern tailed blue

Polyommatus comyntas Godart "1819" [1824]:660 (type-locality "North America").
Lycaena comyntas: Worthington 1880:48; Holland 1931:269.
Everes comyntas: Klots 1951:163; dos Passos 1964:66 (No. 469).

Illinois records.—Map 62.

This is one of the commonest butterflies of Illinois. It is abundant and generally distributed throughout the state. The name *meinersi* Field applies to the spring form of the species, in which females possess much blue dorsally. We have records of *comyntas* from nearly every county, more than for any other butterfly species. The earliest date of capture is April 21, and it has been taken as late as November 29 (Williamson County).

The species is multiple-brooded, and adults often show a degree of seasonal variation. For example, spring males are usually paler than summer forms, and females show moderate to extensive blue scaling dorsally. Summer females are dark brown dorsally with little or no blue scaling.

Glaucopsyche lygdamus couperi Grote
Silvery blue

Glaucopsyche couperi Grote 1874:185 (type-locality "Anticosti Island").
Lycaena lygdamas: Worthington 1880:48.
Lycaena lygdamus: Holland 1931:262.
Glaucopsyche lygdamus couperi: Klots 1951:168; dos Passos 1964:68 (No. 479c).

Illinois records.—Map 63.

Apparently limited to extreme northeastern Illinois, *couperi* (Fig. 2) has been locally common in the past but is now believed to be confined to only a few localities. The principal colonies were at Palos Park, Cook County, and near Elgin, Kane County. We believe the species to be extinct at Palos Park, due to construction in the very restricted area where it occurred; the last known captures there were by Leuschner in 1951 (RL). It apparently still survives near Elgin, where Bristol has taken it as recently as May 2, 1963 (JRH). The only other recent Illinois record is from near Chain-o-Lakes Park, Lake County, May 23, 1954, Perkins (OAP). All other records are relatively old. There is one brood, and the species has been taken from April 13 through May 30.

Holland (1931) thought that *lygdamus* and *couperi* were separate species, with the latter having a more boreal distribution, and *lygdamus* applying to our population. Bower (1911) reported that the Palos Park populations utilized two species of *Lathyrus* as a larval food plant. Adults were on the wing in early May.

Celastrina argiolus pseudargiolus (Boisduval & Le Conte)
Spring azure

Argus pseudargiolus Boisduval & Le Conte 1833:118 (type-locality "United States").
Lycaena pseudargiolus: Worthington 1880:48; Holland 1931:256.
Lycaenopsis argiolus pseudargiolus: Klots 1951:169.
Celastrina argiolus pseudargiolus: dos Passos 1964:69 (No. 481b).

Illinois records.—Map 64.

This species is common and generally distributed throughout Illinois. It has exceedingly complex seasonal variation and brood relationships. Spring individuals are smaller than those in the summer and tend to be confined to woods. Illinois spring material appears to

represent the form *violacea* (Edwards). A single individual representing or approaching *marginata* (Edwards) is in the INHS collection, labeled only "N. Ill." The larger members of the summer brood tend to range more widely into open country and appear to be *neglecta* (Edwards). F. M. Brown regarded specimens taken at Streator, La Salle County, March 28, 1946, April 28, 1954, and June 15, 1954, Irwin (INHS) as intermediates between *violacea* and *neglecta*. The relationships between the various forms of this species are much more complex than the above very generalized statements imply. Shapiro (1966) gave an account of the species as it exists in the Delaware Valley of Pennsylvania; it is likely that similar relationships between the forms of the species prevail in Illinois. All Illinois material appears to be of the subspecies *pseudargiolus*. We have seen nothing approaching *C. a. lucia* (Kirby) from the state, nor do we regard its occurrence here as probable, although it was listed as a separate species by French (1879). Extreme dates of Illinois records are March 28 and September 5.

In the Pine Hills, Union County, the immature stages feed on New Jersey tea, *Ceanothus americanus* L. var. *pitcheri* Torr.

LIPHYRIDAE

Feniseca tarquinius (Fabricius)
Harvester

Hesperia tarquinius Fabricius 1793:319 (type-locality "West Indies").
Feniseca tarquinius: Worthington 1880:48; Holland 1931:245; Klots 1951:150; dos Passos 1964:59 (No. 429).

Illinois records.—Map 65.

The harvester is probably generally distributed in Illinois. The lack of records from many areas probably reflects lack of collecting, or overlooking of the species, rather than its absence. Although it is usually scarce and sporadic in appearance, only one or two adults at a time ordinarily being observed, records indicate that it may occasionally appear in greater numbers—"many" at Northbrook, Cook County, September 7 through September 18, 1967 (Heitzman 1968) and "several" at Elsah, Jersey County, July 14, 1943, Starrett (CLR). The flight is slow, and peculiarly wandering with many gyrations. Harvesters have been recorded from April 14 through November.

In placing this species in the family Liphyridae we follow Clench (1955).

The larvae of *tarquinius* are carnivorous on various species of woolly aphids and represent the only North American butterfly with obligate animal-eating habits. The aphid hosts show up readily on their host plants, mainly alder (*Alnus*) and beech (*Fagus*).

LIBYTHEIDAE

Libytheana bachmanii (Kirtland)
Snout butterfly

Libythea bachmanii Kirtland 1851:189 (type-locality "Mahoning County, Ohio").
Libythea bachmanni: Worthington 1880:48; Holland 1931:210.
Libytheana bachmannii: Klots 1951:121.
Libytheana bachmanii: dos Passos 1964:70 (No. 482).

Illinois records.—Map 66.

The status of this distinctive butterfly in Illinois is parallel to that of the preceding species. It is probably statewide in occurrence, although records are lacking from the northwestern counties. *L. bachmanii* is sporadic and generally uncommon but occasionally appears in large numbers in southern Illinois. According to Klots (1951) it is multivoltine. Date records range from May 8 through September 17.

NYMPHALIDAE

Anaea andria Scudder
Goatweed butterfly

Anaea andria Scudder 1875:248 (type-locality "Mississippi Valley westward to Great Plains; Texas"); Holland 1931:173; Klots 1951:117; dos Passos 1964:70 (No. 484).
Paphia audria: Worthington 1880:48 (*lapsus calami*)

Illinois records.—Map 67.

We have no records of this butterfly from the northwestern counties, and it may not be present there. Elsewhere there are only scattered records. The species is local and rare northward, becoming commoner southward and abundant in southern Illinois. At Streator, La Salle County, we found it one of the rarest of all regularly occurring butterflies. There was a small colony within the city limits which was destroyed about 1944; the species has been taken only twice since then. At Elsah, Jersey County, however, Remington regarded it as "one of our commonest nymphalid butterflies" (CLR). These extremes illustrate the dramatic increase in abundance of *andria* from north to south in the state. There are two broods, the first in mid-July and the second, in greater numbers, appearing in mid-August. The second brood hibernates and reappears in the spring flying until the end of June. The earliest and latest records for this species in Illinois are from April 5 through November.

Asterocampa celtis (Boisduval & Le Conte)
Hackberry butterfly

Apatura celtis Boisduval & Le Conte 1833:210 (type-locality "Georgia"); Worthington 1880:48.
Asterocampa celtis: Holland 1931:168; Klots 1951:12 dos Passos 1964:71 (No. 492).

Illinois records.—Map 68.

The hackberry butterfly is generally distributed throughout Illinois and is locally common in association with its host, hackberry (*Celtis*). *A. celtis* is double brooded. The extreme dates of capture are April 4 and September 24, and the period of greatest abundance is in August. Individuals show a marked tendency to return to the same perch when sunning and will dart out at any insect flying past. They are almost pugnacious at times and may return to the shoulders or net of the collector if they once alight out of curios

Asterocampa clyton (Boisduval & Le Conte)
Tawny emperor

Apatura clyton Boisduval & Le Conte 1833:208 (type-locality "southern United States"); Worthington 1880:48.
Asterocampa clyton: Holland 1931:169; Klots 1951: 119; dos Passos 1964:71 (No. 494).

Illinois records.—Map 69.

This species occurs throughout Illinois. It is local, usually associated with *A. celtis* and having the same host plant, and is far less common than *celtis*. *A. clyton* tends to fly and rest higher in the trees than does *celtis* and may thus be overlooked. Dimorphism exists in both sexes; some specimens having light hind wings with prominent spots (typical *clyton*), others having the hind wings heavily suffused with black (*proserpina*). *A. clyton* is probably single-brooded in Illinois. The earliest and latest dates of appearance are June 18 and August 30.

Limenitis arthemis arthemis (Drury)
White admiral, banded purple

Papilio arthemis Drury 1773(2):17 (type-locality "New York").
Limenitis arthemis: Worthington 1880:48; Klots 1951: 115; dos Passos 1964:74 (No. 516).
Basilarchia arthemis: Holland 1931:164.

Platt & Brower (1968), on the basis of genetic studies and genitalic characters, established that *Limenitis arthemis* and *L. astyanax,* long considered separate species, are actually conspecific. In the narrow belt of territory where the ranges of the northern *arthemis* and the southern *astyanax* meet, there appear various intergrades between the two subspecies. Northern Illinois lies within this zone, and several such intergrades have been taken there. Various names have been proposed for these intergrades, principally *proserpina* Edwards and *albofasciata* Newcomb, but we prefer to discuss the Illinois intergrades in terms of the categories of intergradation erected by Platt & Brower (*loc. cit.*) on the basis of the degree of expression of the white band. Such intergrades are rarely met within northern Illinois, but the few that we have examined represent almost all categories in intergradation between *arthemis* and *astyanax*.

A specimen taken at Chicago, Cook County, no date, Selinger (FMNH) is indistinguishable from typical *arthemis* except for the absence of red spots on the dorsal hind wing, and the presence of two rows of blue-green iridescent patches; the white bands are complete and fully developed. Another taken at Oak Park, Cook County, July 29, 1946, Solem (FMNH) is similar, except that the bands, while complete, are slightly narrower. This agrees closely with Platt & Brower's Category 2. A similar example was captured in a forest preserve near Willow Springs, Cook County, August 23, 1966, Brady (TGB). Category 3 is represented by a specimen taken at Streator, La Salle County, August 9, 1946, Irwin (INHS) (Fig. 3). Another from Chicago, Cook County, June 15, 1902, Gerhard (FMNH) appears to fall within Category 4. These are the only Illinois intergrades we have examined. Others have been reported to us during this study or recorded in the literature, but in the absence of specimens it is impossible to determine the degree of intergradation which they represent. We have not seen entirely typical *arthemis* from Illinois and doubt that it occurs, since the state lies somewhat south of its normal range. French (1879) listed *proserpina* as a separate species, but Worthington (1880) considered it a variety of *arthemis*. Blatchley (1891) recorded *arthemis* from Lake County, Indiana, taken by Worthington, and Masters & Masters (1969) listed it from Lake and Porter counties, Indiana. All these records may be based on *arthemis*-like intergrades, but the possibility of the occurrence of the nominate subspecies in extreme northern Illinois as a casual cannot be entirely ruled out.

Limenitis arthemis astyanax (Fabricius)
Red spotted purple

Papilio astyanax Fabricius 1775:447 (type-locality "America").
Limenitis ursula: Worthington 1880:48.
Basilarchia astyanax: Holland 1931:164.
Limenitis arthemis astyanax: Klots 1951:116.
Limenitis astyanax: dos Passos 1964:74 (No. 517).

Illinois records.—Map 70.

This, the southern subspecies of *arthemis,* is common and statewide in distribution. Extreme dates of capture in Illinois are April 25 and September 9.

Limenitis archippus (Cramer)
Viceroy, mimic

Papilio archippus Cramer 1776(1):24 (type-locality "Jamaica").
Limenitis dissippus: Worthington 1880:48.
Basilarchia archippus: Holland 1931:165.
Limenitis archippus: Klots 1951:114; dos Passos 1964: 75 (No. 518).

Illinois records.—Map 71.

The viceroy is a common and familiar butterfly found throughout Illinois. The earliest and latest dates of observance for this species are May 9 and September 20, and it is most numerous in late July and August.

The larvae feed on willow (*Salix*) and poplar (*Populus*), and adults are usually seen in open meadows and roadsides, most commonly where the host plants occur.

Vanessa atalanta rubria (Fruhstorfer)
Red admiral

Pyrameis atalanta rubria Fruhstorfer 1909:94 (type-locality restricted to "Mexico" by Field 1971:17 by designation of lectotype).
Pyrameis atalanta: Worthington 1880:48.
Vanessa atalanta: Holland 1931:153; Klots 1951:107; dos Passos 1964:77 (No. 527).

Illinois records.—Map 72.

Another common butterfly statewide in distribution, the red admiral is one of the earliest nymphalids to appear in the spring. There are at least two broods, and the long flight season suggests the possibility of an additional brood. Extreme dates of capture are March 27 and November 4. Field (1971) showed that the

North American population of this Holarctic butterfly is properly referred to the subspecies *rubria* (Fruhstorfer).

Cynthia virginiensis (Drury)
American painted lady

Papilio cardui virginiensis Drury 1773(1):10 (type-locality restricted to "Virginia" by Field 1971:49).
Pyrameis huntera: Worthington 1880:48.
Vanessa virginiensis: Holland 1931:154; Klots 1951: 108; dos Passos 1964:77 (No. 528).

Illinois records.—Map 73.

This insect, formerly known as Hunter's butterfly, occurs throughout Illinois and is frequent to common. Like *V. atalanta,* it is characteristic of spring when overwintered individuals appear, but it flies throughout the season until autumn. Although Klots (1951) stated that *virginiensis* is subject to the fluctuations in numbers which are characteristic of the genus, Shapiro (1966) disagreed with this statement. Our observations of the species in Illinois lead us to concur with the latter author. Probably there are three broods in Illinois. The earliest date of capture is April 13 and the latest is October 2. In the generic placement of this species and the next we follow Field (1971).

Cynthia cardui (Linnaeus)
Painted lady, cosmopolite

Papilio cardui Linnaeus 1758:475 (type-locality restricted to "Sweden" by Verity & Querci 1924:42).
Pyrameis cardui: Worthington 1880:48.
Vanessa cardui: Holland 1931:154; Klots 1951:107; dos Passos 1964:77 (No. 529).

Illinois records.—Map 74.

The painted lady, generally considered the most widely distributed butterfly in the world, has been recorded from all parts of Illinois. It is, however, subject to great variation in abundance from year to year, in some seasons being common to abundant, and in others extremely scarce or virtually absent, The species is strongly migratory, and it is believed that breeding populations are reinforced by immigration during periods of abundance. The controlling factors of this fluctuation are not known with certainty. As in other species of *Cynthia,* there is also seasonal variation in size and color, the "wet" forms being large and brightly colored and "dry" forms being smaller and duller. Exceedingly aberrant individuals also occur from time to time, but none is known from Illinois. Records of capture range from April 7 through October 5.

Precis coenia (Hübner)
Buckeye

Junonia coenia Hübner "1806" [1822]: Plate 245 (type-locality restricted to "Cuba" by Comstock 1944: 453); Holland 1931:156; dos Passos 1964:78 (No. 531).
Junonia lavinia: Worthington 1880:48.
Precis lavinia coenia: Klots 1951:108.

Illinois records.—Map 75.

Although Klots (1951) stated that there is a lack of complete understanding of the relationships of the various forms of this species, the student of Illinois butterflies need not concern himself with this problem, for all Illinois material appears to be homogeneous and to represent the nominate *coenia.* However, the seasonal variation that characterizes the species, *e. g.* "wet" and "dry" forms, does exist. We believe that *P. coenia* occurs throughout Illinois, and probably breeds throughout the state as well, but the resident population is thought to be annually reinforced, especially northward, by immigration from the south. The species appears to be less common northward. *P. coenia* is evidently double-brooded, and the second (mid-August) brood is larger in numbers than the first. It has been taken from April 24 through October 29 but is most numerous in late July through September. Adults are wary insects, exceedingly difficult to approach. We follow Tilden ("1970" [1971]) in uniting the genera *Precis* and *Junonia.*

Nymphalis vau-album j-album
(Boisduval & Le Conte)
Compton tortoise shell

Vanessa j-album Boisduval & Le Conte 1833:185 (type-locality "New York, Philadelphia, and New Harmony, Indiana").
Grapta j-album: Worthington 1880:48.
Aglais j-album: Holland 1931:152.
Nymphalis j-album: Klots 1951:105.
Nymphalis vau-album j-album: dos Passos 1964:78 (No. 533a).

Illinois records.—Map 76.

Recorded only from Cook, Lake, and Kane counties in extreme northeastern Illinois, this distinctive butterfly occurs there consistently but usually rarely, probably at the southern limits of its range in the United States. In some seasons, however, *e. g.* 1893 (Snyder 1896) and 1949 (P. S. Remington 1949) it appears in greater numbers than usual. The species is notably periodic, and it is probable that these seasons of comparative numbers coincide with its years of abundance farther north in the main portion of its range. It probably does not breed in our area. The species has been recorded on March 27 (probably an overwintered individual) and from July 15 through October 2

Nymphalis californica (Boisduval)
California tortoise shell

Vanessa californica Boisduval 1852:306 (type-locality "California").
Aglais californica: Holland 1931:152.
Nymphalis californica: Klots 1951:278; dos Passos 1964: 78 (No. 534).

Illinois records.—Cook County: Chicago, at light inside building on Illinois Institute of Technology campus, August 20, 1952, L. S. Phillips (FMNH) (Phillips 1961, 1966).

Obviously casual, the specimen was probably transported here by artificial means in some development stage. However, the species has also been found in Michigan (Moore 1960), Iowa (Phillips 1966), Pennsylvania (Clench 1954), and New York (Klots 1951

Nymphalis milberti (Godart)
Milbert's tortoise shell

Vanessa milberti Godart 1819:307 (type-locality

stricted to "Philadelphia, Pennsylvania" by dos Passos 1938:72); Worthington 1880:48.
Aglais milberti: Holland 1931:153.
Nymphalis milberti: Klots 1951:106; dos Passos 1964: 78 (No. 535).

Illinois records.—Map 77.

Like *N. v-a. j-album, milberti* is a species of variable numbers from year to year. In normal seasons it is rare or absent in northern Illinois, but in years of abundance it may be found in some numbers. One such year was 1967, when it was taken in several localities, especially at Freeport, Stephenson County in August and September (RAA), and also at Streator, La Salle County, where it had not previously been found. Also abundant in 1949 in the Chicago area (P. S. Remington 1949). *N. milberti* is found much more frequently than *N. v-a. j-album* and extends farther south in Illinois. It has been taken from June 11 through November 11, but the majority of records are between late August and early October.

Nymphalis antiopa (Linnaeus)
Mourning cloak

Papilio antiopa Linnaeus 1758:476 (type-locality restricted to "Sweden" by Verity & Querci 1924:43).
Vanessa antiopa: Worthington 1880:48.
Aglais antiopa: Holland 1931:153.
Nymphalis antiopa: Klots 1951:106; dos Passos 1964: 79 (No. 536).

Illinois records.—Map 78.

The mourning cloak is generally distributed in Illinois and is common. Shapiro (1966) stated that it is subject to the same periodicity as its congeners, but our observations of the species in Illinois seem to indicate that this fluctuation in numbers, if present at all, is much less noticeable in this butterfly than in its relatives. The species hibernates as an adult, emerging early in the spring and flying throughout the season. The insect has one of the longest seasons of any of the Illinois butterflies, appearing as early as March 3 and as late as November 20.

Polygonia interrogationis (Fabricius)
Question mark

Papilio interrogationis Fabricius 1798:424 (type-locality "North America").
Grapta interrogationis: Worthington 1880:48.
Polygonia interrogationis: Holland 1931:149; Klots 1951:102; dos Passos 1964:79 (No. 537).

Illinois records.—Map 79.

The question mark is the largest, commonest, and most familiar member of the genus *Polygonia* and is statewide in distribution. It is seasonally dimorphic; we have found the lighter winter form *fabricii* (= typical *interrogationis*) a little less common than the dark summer form *umbrosa*. Earliest and latest dates of capture in Illinois are April 13 and November 3.

Polygonia comma (Harris)
Hop merchant, comma

Vanessa comma Harris 1841:221 (type-locality "Massachusetts").
Grapta comma: Worthington 1880:48.
Polygonia comma: Holland 1931:149; Klots 1951:103; dos Passos 1964:79 (No. 538).

Illinois records.—Map 80.

The comma is, like the question mark, found throughout Illinois but is less common than that species. It exhibits similar seasonal dimorphism. Overwintered adults frequently appear in March and are among the earliest butterflies on the wing in early spring. Records range from March 17 to November 7.

Polygonia faunus (Edwards)
Green comma

Grapta faunus Edwards 1862*b*:222 (type-locality restricted to "Hunter, [Greene County,] New York" by Brown 1967:338 by designation of lectotype); Worthington 1880:48.
Polygonia faunus: Holland 1931:150; Klots 1951:104; dos Passos 1964:79 (No. 540).

Illinois records.—Carroll County: Palisades State Park, July 20, 1963, Laibly (DL).

We examined the specimen on which the above record is based. Laibly reported that two more were taken at the same locality in 1964, but these were not seen. From this record, Laibly's statement, and the presence of the species in Worthington's list, it may be inferred that *faunus* is a species of consistent but rare occurrence in extreme northern (probably only northwestern) Illinois.

Polygonia progne (Cramer)
Gray comma

Papilio progne Cramer 1776(1):9 (type-locality "Jamaica and New York").
Grapta progne: Worthington 1880:48.
Polygonia progne: Holland 1931:151; Klots 1951:104; dos Passos 1964:80 (No. 546).

Illinois records.—Map 81.

This butterfly is local and uncommon in Illinois and is not recorded from the southern portion of the state, where it may not occur. The most southerly record is from Elsah, Jersey County, where Remington found it uncommon (CLR). It is very rare in the Chicago area, recorded from Cook County, without definite locality, by Schatz and Boughner (LS, JLB). A number, however, were taken in a forest preserve near Willow Springs, in August, 1966, by Arnold, Brady, and Irwin (RRI); it has been taken there also in subsequent years. The species is rare at Streator, La Salle County (RRI) but reported common at Danville, Vermilion County (TE), and in Perryton Township, Mercer County (PJC). Le Baron (1871) described damage to currant bushes by the larvae in Kankakee County. It has been taken in April and between June 13 and October 26.

Chlosyne nycteis (Doubleday)
Silvery checkerspot

Melitaea nycteis Doubleday 1847:181 (type-locality "middle United States"); Klots 1951:98.
Phyciodes nycteis: Worthington 1880:47; Holland 1931: 136.

Chlosyne nycteis: dos Passos 1969*a*:117 (No. 548).

Illinois records.—Map 82.

C. nycteis is a common, widely distributed butterfly in Illinois. It is probably double-brooded throughout the state with broods appearing approximately at mid-June and mid-August in the north and earlier southward. The earliest and latest record dates are April 23 and September 17.

Chlosyne gorgone carlota (Reakirt)
Gorgone checkerspot

Melitaea nycteis Edwards (*nec* Doubleday) 1861:161 (type-locality "Illinois; Missouri").
Eresia carlota Reakirt 1866*a*:141 (new name).
Phyciodes carlota: Worthington 1880:47.
Phyciodes gorgone: Holland 1931:139.
Melitaea gorgone carlota: Klots 1951:95.
Chlosyne gorgone carlota: dos Passos 1969*a*:117 (No. 549b).

Illinois records.—Map 83.

Although long known from Illinois, this checkerspot (Fig. 2) has undergone a dramatic population explosion in the state within the past few years. Previously it appears to have been uncommon to rare. This increase in numbers and distribution began in the early 1960's. In 1963, Taylor found it common at Mason State Forest, Mason County, between June 16 and June 23 (TT). It was first taken at Streator, La Salle County, on July 22, 1964, by Gary McCoy (GMcC). The following two seasons it abounded everywhere in that area. It was reported as common at Perryton Township, Mercer County (PJC). A considerable number were observed by Irwin at Cahokia, St. Clair County, on June 13–14, 1970. All records of *carlota* in Illinois in our files date from 1963 and later except one from Lacon, Marshall County, September 13, 1925, R. M. Barnes (ISM), and Elsah, Jersey County, May 9, 1942, C. L. Remington (CLR). It has been taken between May 8 and September 13.

Chlosyne harrisii (Scudder)
Harris' checkerspot

Melitaea harrisii Scudder 1864:167 (type-locality "Norway, Maine; Pittsfield, New Hampshire; Princeton, Massachusetts"); Klots 1951:94.
Phyciodes harrisii: Worthington 1880:47.
Melitaea harrisi: Holland 1931:126.
Chlosyne harrisii: dos Passos 1969*a*:117 (No. 550).

Illinois records.—Kane County: Elgin, June 21, 1931, Bristol (INHS) (Fig. 2). Vermilion County: Danville, August 20, 1960, Ellis (TE).

We examined both of the above specimens. *C. harrisii* should be of more frequent occurrence in Illinois than the few authentic records indicate. It may be overlooked because of its superficial resemblance to *C. nycteis*. The species was credited to Illinois by both Holland and Klots.

Phyciodes texana (Edwards)
Texan crescent

Eresia texana Edwards 1863*b*:81 (type-locality restricted to "Neu Braunfels, Comal County, Texas" by Brown 1966*b*:421).
Anthanassa texana: Holland 1931:141.
Phyciodes texana: Klots 1951:101; dos Passos 1969*a*:119 (No. 563).

Illinois records.—Jersey County: Elsah (campus of Principia College), positive sight record of a male, October 25, 1940, C. L. Remington (CLR).

The specimen was probably a windblown stray. The species has also been taken at Cedar Hill, Missouri, about 45 miles south of Elsah (CLR).

Phyciodes tharos (Drury)
Pearl crescent

Danaus tharos Drury 1773(1):43 (type-locality "New York").
Phyciodes tharos: Worthington 1880:47; Holland 1931:135; Klots 1951:100; dos Passos 1969*a*:119 (No. 566).

Illinois records.—Map 84.

One of our commonest butterflies, the diminutive pearl crescent abounds throughout the state from late spring through autumn. The seasonal variation characteristic of *tharos* occurs in Illinois, and a number of the aberrations which the species tends to produce, probably caused by cold weather, have been taken. Extreme dates on record are April 20 and October 19.

Phyciodes batesii (Reakirt)
Tawny crescent

Eresia batesii Reakirt "1865" [1866]:226 (type-locality "Winchester, Virginia; Gloucester, New Jersey").
Phyciodes batesi: Holland 1931:136.
Phyciodes batesii: Klots 1951:100; dos Passos 1969*a*:120 (No. 567).

Illinois records.—La Salle County: Streator, June 28, 1965, Irwin (INHS) (Fig. 2).

We submitted this specimen to F. M. Brown for examination and he wrote us as follows: "I think it probably *batesii*. It is not really typical of either *batesii* or *tharos*. The black marks on the fore wing (underside) are intermediate and the margin is *tharos*. The under hind wing is strictly *batesii*. The upperside the fore wing is definitely *tharos*, the hind wing intermediate. The only clear evidence is the under hind wing. The locality is outside the usual range for *batesii* being a little too far south. The date is OK (May–June)." We include *batesii* in the Illinois list solely on the basis of this apparently intermediate specimen; further evidence of its occurrence in the state is needed.

Euphydryas phaeton phaeton (Drury)
Baltimore

Danaus phaeton Drury 1773(1):42 (type-locality "New York").
Melitaea phaeton: Worthington 1880:47.
Melitaea phaëtona: Holland 1931:115.
Euphydryas phaeton phaeton: Klots 1951:93; dos Passos 1969*a*:122 (No. 592).

Illinois records.—Map 85.

Comparatively few specimens of this butterfly

known from Illinois. It probably exists in widely scattered, strongly localized colonies throughout its range. From the limited material which has been available for study, we have learned that there are two subspecies of *phaeton* in Illinois. The nominate subspecies appears to be limited to the northern half of the state; all specimens which we have seen from Ogle, Kane, and Lake counties are clearly typical *phaeton*. Southward, the subspecies *E. p. ozarkae* Masters occurs, and there is an abrupt clinal separation between the two populations. A specimen from Peoria, Peoria County, June 6, 1959, Taylor (INHS) seems to be somewhat intermediate but closer to *E. p. phaeton*. The butterfly is single-brooded, and it has been taken in Illinois between June 6 and July 4.

Our distribution map depicts Illinois records of both subspecies of *phaeton*, as well as records based on specimens which were not studied, and which were therefore not determinable to subspecies, although from their geographic location in the state this may be inferred.

Euphydryas phaeton ozarkae Masters

Euphydryas phaeton ozarkae Masters 1968:87 (type-locality "Lynch Hollow, Camden County, Missouri").

Illinois records.—Map 85.

This recently described subspecies occurs in the southern half of Illinois. It is readily separable from nominate *E. p. phaeton* by its larger size and reduction in the red coloring. The marginal red spots are smaller, and those in the fore-wing cell are reduced or absent; the red is paler and more yellowish than in *E. p. phaeton*. Masters (*loc. cit.*) indicates that there are striking differences in the biology of *E. p. phaeton* and *E. p. ozarkae*; the latter is associated with *Aureolaria* rather than *Chelone glabra*, the host of nominate *phaeton*. It flies on high, dry hillsides rather than in marshy areas; the flight is faster and stronger, and the males tend to stray farther from the host plant than do those of *E. p. phaeton*.

Material which we have examined from Macoupin, Jackson, and Union counties may be assigned to this taxon. A female from Carlinville, Macoupin County, with a fore wing length of 33 mm, was compared with a paratype of *E. p. ozarkae* and found to agree well with it, whereas a male taken in Giant City State Park, Jackson County (Fig. 3), conforms to this subspecies in all respects and lacks all trace of red in the fore wing cell.

Dates of capture of *E. p. ozarkae* in Illinois are between May 30 and June 13, coinciding with the flight period described by Masters (*loc. cit.*).

Boloria selene myrina (Cramer)
Silver bordered fritillary

Papilio myrina Cramer 1777(2):141 (type-locality "New York").
Argynnis myrina: Worthington 1880:47.
Brenthis myrina: Holland 1931:105.
Boloria selene myrina: Klots 1951:89; dos Passos 1964:89 (No. 598b).

Illinois records.—Map 86.

We have records of this species only from the northern half of Illinois. Although Klots (1951) referred to its presence in southern Illinois, we doubt its occurrence there. It appears to have increased in distribution and numbers in recent years. It was first taken at Streator, La Salle County, in 1968 and was locally abundant there in 1968–1969. It was also abundant at Goose Lake Prairie, Grundy County, in 1968–1970. Probably three broods occur in Illinois. The earliest date of capture is May 12 and the latest is September 20.

Boloria bellona (Fabricius)
Meadow fritillary

Papilio bellona Fabricius (*nec* Cramer) 1775:517 (type-locality "North America").
Argynnis bellona: Worthington 1880:47.
Brenthis bellona: Holland 1931:111.
Boloria toddi ammiralis: Klots 1951:92; dos Passos 1964:89 (No. 599b).

Illinois records.—Map 87.

This fritillary is restricted primarily to northeastern Illinois. Although locally common, it does not appear to be as generally distributed as *myrina*. There are many records of the species from Cook County, but none are recent. We have records from Goose Lake Township, Grundy County, and Streator, La Salle County, in association with the more numerous *selene*. It is locally abundant near Danville, Vermilion County, but *selene* has not been recorded from there. This species is a denizen of wet meadows, the habitat also favored by *selene*. It is probably triple-brooded. It has been recorded from May 1 through September 14.

The name *bellona* (Fabricius) was validated by the International Commission on Zoological Nomenclature in Opinion 516 of January 12, 1958.

Speyeria idalia (Drury)
Regal fritillary

Papilio idalia Drury 1773(1):25 (type-locality restricted to "New York City, New York County, New York" by dos Passos & Grey 1947:9).
Argynnis idalia: Worthington 1880:47; Holland 1931:84.
Speyeria idalia: Klots 1951:86; dos Passos 1964:91 (No. 611).

Illinois records.—Map 88.

This species is exceedingly local but widely distributed and often common where found. It is apparently limited primarily to northern Illinois. Its numbers are subject to a certain amount of fluctuation from year to year. In some areas it occurs very rarely, as at Streator, La Salle County, where two have been taken and a third observed between 1941 and 1971. As in most species of *Speyeria* in Illinois, males tend to appear and disappear earlier in the season than do females. We have records of capture between June 5 and September 23.

Speyeria atlantis (Edwards)
Atlantis fritillary

Argynnis atlantis Edwards 1862*a*:54 (type-locality restricted to "Hunter, [Greene County,] New York" by dos Passos 1935:86); Worthington 1880:47; Holland 1931:90.

Speyeria atlantis: Klots 1951:86; dos Passos 1964:94 (No. 618).

Illinois records.—"Northern Illinois," Gerhard (FMNH). Cook County: Arlington Heights, June 26, 1930, A. L. McElhose (FMNH).

Other reported records could not be verified and are not accepted because of possible confusion with *S. aphrodite*. These specimens were probably casual; the species does not normally range as far south as Illinois.

Speyeria diana (Cramer)
Diana

Papilio diana Cramer 1777(2):4 (type-locality restricted to "Jamestown, James City County, Virginia" by dos Passos & Grey 1947:6).

Argynnis diana: Worthington 1880:47; Holland 1931:84.

Speyeria diana: Klots 1951:86; dos Passos 1964:95 (No. 621).

Illinois records.—"Southern Illinois," no date, French (FMNH); 1890, "B. F." (USNM). Clay County: Snyder (1900). Union County: Cobden 1869, Longley (USNM). Vermilion County: SE of Danville, August 20, 1960, Ellis (TE).

We have seen all of the above *diana* from Illinois except the Clay County record in the literature. The status of *diana* in Illinois at the present time is uncertain. Apparently it was formerly of regular occurrence in the southern third of the state, but at present it must be extremely rare and local, or more probably extinct. Thorough collecting in southern Illinois in recent years has failed to turn up this species, and it may well be that ecological changes have extirpated it. Clark & Clark (1951) mentioned the deforestation of parts of Virginia as a cause of its decline in much of that state, and it seems logical that this may have been a factor in southern Illinois as well.

The only recent Illinois record is from the northern half of the state, which seems peculiar. One may hazard a guess that the Danville specimen, a female, may have followed the nearby Wabash River from further south, as *diana* has been recorded from Evansville, Indiana (Blatchley 1891).

There are many references in the older literature to Illinois *diana*. Edwards (1864) referred to a specimen from southern Illinois in the collection of B. D. Walsh as one of the few then known. Snyder (1900) said that "its northern limit in Illinois is Clay County." Skinner (1896) and Clark & Clark (1951) stated that specimens of *diana* from southern Illinois are larger than those found farther east.

The state distribution map in the files of the Illinois Natural History Survey shows *diana* from "Southern Illinois, 1880," but there are no Illinois specimens in the collection.

Speyeria cybele (Fabricius)
Great spangled fritillary

Papilio cybele Fabricius 1775:516 (type-locality restricted to "New York City, New York County, New York" by dos Passos & Grey 1947:6).

Argynnis cybele: Worthington 1880:47; Holland 1931:86.

Speyeria cybele: Klots 1951:87; dos Passos 1964:95 (No. 622).

Illinois records.—Map 89.

S. cybele is common throughout Illinois. Klots (1951) explained that there is a single, extended brood with more or less continual emergence of the adults during its long season. As is characteristic of the genus, the males appear earlier than do the females. Extreme dates of capture in the state are April 14 and September 9.

Speyeria aphrodite (Fabricius)
Aphrodite

Papilio aphrodite Fabricius 1787:62 (type-locality restricted to "New York City, New York County, New York" by dos Passos & Grey 1947:8).

Argynnis aphrodite: Worthington 1880:47; Holland 1931:88.

Speyeria aphrodite: Klots 1951:87; dos Passos 1964:96 (No. 623).

Argynnis alcestis Edwards "1876" [1877]:289 (type-locality restricted to "Galena, Jo Daviess County, Illinois" by dos Passos & Grey 1947:8); Worthington 1880:47; Holland 1931:88.

Speyeria aphrodite alcestis: Klots 1951:88; dos Passos 1964:96 (No. 623c).

Illinois records.—Map 90.

S. aphrodite is apparently limited to the northern half of Illinois. It is much less common and more local than *cybele* and has a shorter flight season. We do not consider that *alcestis* is a subspecies of *aphrodite*. It flies in company with typical *aphrodite* consistently, not only in Illinois, but in northern Indiana and southern Michigan. It is therefore either a color variety of *aphrodite* or a separate species. We have records of *aphrodite* from June 15 through September 2. French (1879) listed *alcestis* as a separate species.

Euptoieta claudia (Cramer)
Variegated fritillary

Papilio claudia Cramer 1776(1):109 (type-locality "Jamaica").

Euptoieta claudia: Worthington 1880:47; Holland 1931:80; Klots 1951:84; dos Passos 1964:96 (No. 624).

Illinois records.—Map 91.

This essentially southern species is statewide in occurrence. It is somewhat irregular and less numerous northward. There are at least two broods, and they have a long flight season. The earliest and latest dates are April 24 and November 12, and most records are from late July through September.

Agraulis vanillae nigrior Michener
Gulf fritillary

Agraulis vanillae nigrior Michener 1942:7 (type-locality "Upper Matecumbe Key, Florida"); Klots 1951:82; dos Passos 1964:97 (No. 630a).

Agraulis vanillae: Worthington 1880:47.

Dione vanillae: Holland 1931:79.

Illinois records.—Map 92.

Turner (1963) described a colony of *vanillae* which survived for three winters in west-central Missouri. The species may therefore occasionally breed in southern Illinois at approximately the same latitude. The finding of larvae at Alton, Madison County, supports this belief (P. S. Remington 1951). McNeese reported seeing several *vanillae* at Centreville, St. Clair County (personal communication); he took a newly emerged male on September 2, 1966 (INHS) (Fig. 3). Two species of the host plant, passionflower (*Passiflora*) occur in southern Illinois—*P. incarnata* as far north as St. Clair, Wayne, and Wabash counties, and *P. lutea* throughout the southern half of the state as far north as Champaign and Vermilion counties (Jones & Fuller 1955). The Kane County record, and possibly the Cass and Champaign County records, are probably of strays. Illinois *vanillae* are assigned to the subspecies *nigrior* Michener on the authority of Klots (1951).

DANAIDAE

Danaus plexippus (Linnaeus)
Monarch, milkweed butterfly

Papilio plexippus Linnaeus 1758:471 (type-locality restricted to "Pennsylvania" by the International Commission on Zoological Nomenclature, Opinion 282, October 1, 1954).
Danais archippus: Worthington 1880:47.
Danais plexippus: Holland 1931:68.
Danaus plexippus: Klots 1951:77; dos Passos 1964:98 (No. 631).

Illinois records.—Map 93.

The monarch is familiar to nearly everyone. It is usually common to abundant but sometimes variable in numbers from year to year. The well-known migratory pattern characteristic of the butterfly is frequently observed in Illinois in the autumn. We refer all Illinois *plexippus* to the nominate subspecies on the advice of Klots (1951); the record by Clark (1941) of *D. p. melanippe* (Hübner) from Decatur, Macon County, would probably be regarded as an individual variant approaching the appearance of *melanippe*. The species has been recorded from April 20 through November 13.

Danaus gilippus strigosus Bates
Queen

Danais strigosa Bates 1864:32 (type-locality "Guatemala").
Danais berenice strigosa: Holland 1931:69.
Danaus gilippus strigosus: Klots 1951:78; dos Passos 1964:98 (No. 633b).

Illinois records.—Cook County: Palos Park, in field, September 9, 1928, Henderson (AKW).

Wyatt informed us that he had seen this specimen and that it is an authentic record. Although undoubtedly a casual stray, not forming a part of the Illinois butterfly fauna, the species has also been taken in Ohio (Gilbert 1960).

SATYRIDAE

Lethe portlandia anthedon (Clark)
Pearly eye

Enodia portlandia anthedon Clark 1936*a*:255 (type-locality "Lava, Sullivan County, New York").
Debis portlandia: Worthington 1880:48.
Enodia portlandia: Holland 1931:177.
Lethe portlandia anthedon: Klots 1951:66; dos Passos 1964:99 (No. 636c).

Illinois records.—Map 94.

This butterfly is extremely local, strongly limited to woodland environments, and often common where found. Exceedingly swift and wary, it is often difficult to capture.

All Illinois material which we have studied, including that from the southernmost portion of the state, represents *L. p. anthedon*. The nominate subspecies had been expected to occur in extreme southern Illinois, but no Illinois specimens thus far known appear to be assignable to that taxon. *L. p. portlandia* is associated with cane (*Arundinaria*), which occurs in the southern third of Illinois; *L. p. anthedon* evidently utilizes other grasses which are generally distributed throughout Illinois. Extreme dates of capture are April 7 and September 14, though the validity of the former date, a record from Elk Grove, Cook County, appears questionable. The next earliest date is May 24. The species is probably double-brooded in Illinois, appearing in numbers in early June and again about mid-August.

Lethe creola (Skinner)
Creole pearly eye

Debis creola Skinner 1897:236 (type-locality "Opelousas, Louisiana").
Enodia creola: Holland 1931:177.
Lethe creola: Klots 1951:67; dos Passos 1964:99 (No. 637).

Illinois records.—Franklin County: Benton, June 20, 1963 (SIU). Jackson County: Murphysboro, August 4, 1963 (SIU). Pope County: Lusk Creek, near Eddyville, August 12, 1967, Richardson (JCD). Saline County: Stonefort, July 3, 1954, July 4, 1958, August 1, 1959, August 10, 1959, August 30, 1954 (SIU). Union County: Pine Hills, September 1, 1966, Downey (INHS) (Fig. 3).

Most butterfly manuals include Illinois in the range of *creola*, but apparently on the basis of a misidentified specimen of *L. anthedon* reported by Clark (1935, 1936*a*) from Palos Park, Cook County (Irwin 1970). The finding of true *creola* in southern Illinois, where it is established, allows the state record to be retained. It is associated with cane (*Arundinaria*), and restricted to southern Illinois where the plant occurs.

Lethe eurydice (Johansson)
Eyed brown

Papilio eurydice Johansson 1763:406 (type-locality restricted to "Morris Arboretum, Philadelphia County, Pennsylvania" by Cardé, Shapiro, & Clench 1970:74 by designation of neotype).

Neonympha canthus: Worthington 1880:48.
Satyrodes eurydice: Holland 1931:178.
Lethe eurydice: Klots 1951:68; dos Passos 1964:99 (No. 638).

Illinois records.—Map 95.

Until very recently, this species and the following, *Lethe appalachia* R. L. Chermock, were regarded as a single entity, with the latter taxon a subspecies of the former. However, Cardé et al. (*loc. cit.*) discovered that they are actually distinct, widely sympatric, sibling species. Although the same conclusion was reached independently and almost simultaneously by dos Passos (1969*b*), the results of his investigation, including his taxonomic assignments of the entities involved, differ somewhat from those of the former authors.

Shapiro studied all material in the Field Museum and Natural History Survey collections. He found that both species exist in the state. *L. eurydice,* however, is much more widespread than *L. appalachia;* the former is locally common in northeastern Illinois, whereas *appalachia* has thus far been recorded only from Cook County. Only records based upon the material examined by Shapiro have been included herein. Records of "*eurydice*" from a number of other localities in Illinois were obtained during this study, but they have been ignored because it was not possible to check the specimens on which they were founded to determine their true identity.

Foremost among the biological differences between the two species, which initially led to the discovery of their distinctness, is their definite restriction to divergent habitats. *L. eurydice* occurs in open sedge marshes and meadows, occasionally in dry grassy areas, whereas *L. appalachia* inhabits wooded areas and shrub swamps (Cardé, *et al., loc. cit.*; Shapiro, personal communication). None of the Illinois material which was re-examined was habitat associated, and thus this useful additional confirmation of identity is lacking. Future collections of *eurydice* and *appalachia* should be carefully labeled as to habitat.

Morphological differences between *eurydice* and *appalachia* are not great. The genitalia differ somewhat, and Cardé *et al.* (*loc. cit.*) described and figured them. However, color and pattern characters are almost always sufficient for the separation of the two species. One of the most constant of these is the shape of the postmedian lines on the undersides of both wings. In *eurydice,* these lines are jagged and irregular with sharp points, especially near the anal angle of the secondaries, whereas in *appalachia* they are straighter and less jagged, sinuate rather than irregular. The dorsal ground color of *eurydice* is pale brown, the ventral somewhat yellowish; in *appalachia* the dorsal ground color is darker, grayish or mousy brown, with that of the underside tinged with purplish or lilac iridescence. In both nominate *eurydice* and in *appalachia,* there is considerable contrast between the limbal and the basal and discal areas of the dorsal primaries; in *L. eurydice fumosa,* unrecorded from Illinois, there may be less such contrast, giving these wings a more uniform ground color, which is usually darker than in *L. eurydice eurydice,* especially in males.

L. eurydice is single-brooded in Illinois. The dates of capture range from June 14 to August 1.

Lethe appalachia R. L. Chermock

Lethe eurydice appalachia R. L. Chermock 1947:32 (type-locality "Conestee Falls, near Brevard, North Carolina"); Klots 1951:68; dos Passos 1964:99 (No. 638d).
Lethe fumosa appalachia: dos Passos 1969*b*:121.

Illinois records.—Cook County: River Grove, July 4, 1950, July 16, 1950, Kistner (FMNH); Edgebrook [Chicago], July 4, 1913, Wyatt (FMNH); Elmwood Park, July 8, 1934, Herz (FMNH); Schiller Park, July 13, 1940, Camras (FMNH); Palos Park, July 10, 1948 Wren (INHS); Glenview, July 14, 1918, Mares (INHS); Chicago, July 6, 1913, Gunder (AMNH).

The recent elevation of this taxon to full specific rank is discussed above, and the species is characterized in relation to *L. eurydice.* All of the Illinois records quoted above are based upon material studied by Shapiro, none of which was habitat associated.

In addition to the pattern characters described under *L. eurydice,* and those summarized by Cardé, Shapiro & Clench (1970), we have noticed that there is occasionally a tendency toward obsolescence of one or more of the ocelli of the upper side of the fore wings in *appalachia,* which does not seem to occur in *eurydice.*

Localities suitable for the occurrence of *appalachia* exist in northeastern Illinois elsewhere than in Cook County and ought to be investigated for its possible presence.

Euptychia gemma (Hübner)
Gemmed satyr

Neonympha gemma Hübner "1818" [1818]: Plate 49 (type-locality "Georgia"); Worthington 1880:48.
Euptychia gemma: Holland 1931:179; Klots 1951:70; dos Passos 1964:100 (No. 639).

Illinois records.—Map 96.

This Lower Austral butterfly (Fig. 3) is an established resident of the extreme southern counties of Illinois. It is local but common where it occurs. We have records of the species between April 24 and October

Euptychia hermes sosybius (Fabricius)
Carolina satyr

Papilio sosybius Fabricius 1793:219 (type-locality not stated).
Neonympha sosybius: Worthington 1880:48.
Euptychia sosybia: Holland 1931:180.
Euptychia hermes sosybia: Klots 1951:69.
Euptychia hermes sosybius: dos Passos 1964:100 (No. 645b).

Illinois records.—"Illinois," 1♂1♀, no further data (CM, *ex* Marloff collection).

We suspect that *E. h. sosybius* occupies the same general range in Illinois as does *E. gemma.* It is probably not common and may be overlooked because of resemblance to the abundant *E. cymela* on the wing.

Euptychia cymela (Cramer)
Little wood satyr

‡*Papilio eurytus* Fabricius (*nec* Clerck, *nec* Linnae

1775:487 (type-locality "Jamaica").
Papilio cymela Cramer 1777(2):55 (type-locality "Cape of Good Hope").
Neonympha eurytris: Worthington 1880:48.
Euptychia eurytа: Holland 1931:180.
Euptychia cymela: Klots 1951:69; dos Passos 1964:100 (No. 646.)

Illinois records.—Map 97.

This little satyrid is very common in and near woods and is statewide in distribution. There is a single brood, with dates of capture from April 3 to August 23. In northern Illinois, the butterfly generally emerges about the last week in May and is common until early July. The August date quoted above is very late for the species.

Cercyonis pegala olympus (Edwards)
Wood nymph, grayling

Satyrus olympus Edwards 1880*a*:31 (type-locality restricted to "Chicago, Illinois" by Brown 1964:378).
Satyrus alope olympus: Worthington 1880:48.
Cercyonis alope nephele: Holland 1931:189.
Cercyonis pegala nephele: Klots 1951:72.
Cercyonis pegala olympus: dos Passos 1964:102 (No. 656d).

Illinois records.—Map 98.

Because Chicago, Cook County, Illinois, is the typelocality of *C. p. olympus* and following the advice of F. M. Brown, we employ this name for the Chicago area population of this species and for that of Illinois, as a whole. Nearly all Illinois *pegala* have the fore wing above dark, with little or no indication of a yellow patch or band (Fig. 3). Occasional individuals occur, however, in which this yellow band on the fore wings is nearly as well developed as in *C. p. alope*. These are found in association with the dark form, which usually predominates. C. L. Remington, however, indicated that the yellow-banded form was predominant at Elsah, Jersey County (CLR). The relationships between the various final forms of this species are as yet imperfectly known, and extensive breeding experiments will be required to clarify them.

C. p. olympus is separable only by larval characters from *C. p. nephele* (Kirby), the name usually applied to non-yellow-banded populations from eastern North America (see Brown, 1965, 1966*a*). Worthington (1880) listed the insect as *Satyrus alope* Boisduval (*sic*), with *olympus* as a variety of *alope*. This implies that both yellow- and non-yellow-banded populations were included. Edwards (1880*a*:113) discussed at some length the occurrence of the various forms of this species in Illinois, including the basis for Worthington's inclusion of yellow-banded *alope* in his list. Emmel (1969) offered a good recent study of *pegala*.

C. p. olympus is common and widely distributed throughout Illinois. It is most abundant in July and August in open situations as well as in woodlands. It is single-brooded, with the earliest date June 9 and the latest September 12. Two very early dates from the Chicago area, March 28 and May 10, are difficult to explain and may be erroneous.

The *alope*-like yellow-banded individuals have been recorded from the following Illinois localities, from all of which *olympus* has also been recorded: Cook County: Chicago, September 12, 1947, Kistner (FMNH). Fayette County: Ramsey, July 15, 1948, Phillips (LSP). Iroquois County: NE of Beaverville, August 3, 1970, Leeuw (INHS). Jersey County: Elsah (CLR). Livingston County: S of Streator, July 16, 1966, Irwin (INHS). Mercer County: Perryton Township, July 1, 1952, Conway (INHS) (Fig. 3). Peoria County: Peoria, 1957, August 13, 1960, Taylor (TT). Randolph County: Prairie du Rocher, June 27, 1956, Sanderson (INHS). Sangamon County: August 12, 1939, unusually well-marked specimen, Wright (ISM). The yellow-banded phase is thus seen to occur in nearly all parts of the state.

BUTTERFLIES OF POSSIBLE OCCURENCE IN ILLINOIS

In addition to those butterflies actually recorded from Illinois, the following species are considered as "possibles" for future inclusion in the state fauna. Some have already been credited to the state, but sufficient confusion exists about proper identity that we relegate them to this probable list rather than to either positive records or the erroneous records as given in the concluding section. Most of the species cited occur reasonably close to our borders, or this state is located within their known range of distribution.

In this section we omit citations of the original descriptions, type localities, and references to Holland (1931) and dos Passos (1964, 1969*a*, 1970), giving only those to Worthington (1880) if any, and Klots (1951). We omit date citations to these works in the text for the sake of convenience and brevity.

HESPERIDAE

Oligoria maculata (Edwards)
Twin spot skipper

Oligoria maculata: Klots 1951:260.

O. maculata ranges from Florida to Georgia and Alabama, straying to New York, Massachusetts, and Texas, according to Klots, and may therefore occur at least casually in southern Illinois.

Atrytone arogos (Boisduval & Le Conte)
Arogos skipper

Pamphila vitellius: Worthington 1880:49.
Atrytone arogos: Klots 1951:253.

This species may occur in the state, possibly as subspecies *iowa* (Scudder). The range as given by Klots is "Florida and Gulf States, n. to New Jersey, Minnesota, Iowa, and Nebraska," with *A. a. iowa* occupying the northwestern portion of this area. This is the only species listed by Worthington for which occurrence in Illinois has not subsequently been either confirmed or adjudged improbable. French (1879) said that "P. Vitellius is reported from Iowa, but I do not know of it being found in Illinois."

Polites vibex (Geyer)
Whirlabout

Polites vibex: Klots 1951:247.

This skipper may occur northward at least as far as southern Illinois. Klots gave Connecticut and Arkansas as the northern limits of its range. It is generally distributed and quite common in Mississippi (Mather & Mather 1958).

Hesperia metea Scudder
Cobweb skipper

Hesperia metea: Klots 1951:238.

Illinois lies well within the range of this skipper but we have no records from the state. We see no reason why it should not occur in Illinois.

Hesperia attalus (Edwards)
Dotted skipper

Hesperia attalus: Klots 1951:239.

The range as given by Klots was "Florida and Texas, n. to Massachusetts, Ohio, Wisconsin, and Nebraska." It may be expected to occur in Illinois; if it does, it has probably been overlooked or confused with other *Hesperia.*

Oarisma garita (Reakirt)
Garita skipper

Thymelicus garita: Worthington 1880:48.
Oarisma garita: Klots 1951:231.

As previously explained in connection with *Oarisma powesheik,* we believe that the listing of *garita* by French (1879) and Worthington (*loc. cit.*) must have been based on confusion with the former species.

Erynnis lucilius (Scudder & Burgess)
Columbine dusky wing

Erynnis lucilius: Klots 1951:227.

E. lucilius almost certainly occurs at least in northern Illinois, despite the lack of positive records. It is inseparable from *E. baptisiae,* by morphological characters, so that host plant association is essential for its recognition. None of the material labeled *lucilius* which we examined in the Field Museum and Illinois Natural History Survey collections was so associated. In view of this deficiency, we do not feel justified in accepting the records. Although Burns (1964) stated that he had examined an undoubted *lucilius* from the "vicinity of Chicago, Illinois," data for this specimen were unavailable. The term "vicinity of Chicago" has sometimes been used to include closely adjacent northwestern Indiana.

Burns (1964) indicated that *E. lucilius* and *E. baptisiae* are predominantly allopatric, with the former having a northern and the latter a southern distribution with only a narrow belt of territory where they exist in sympatry. For this reason, it is to be expected that *E. lucilius* will be confined to northern Illinois, since *baptisiae* is believed to occur throughout the state. *E. lucilius* feeds upon *Aquilegia* (columbine), and any *Erynnis* found ovipositing upon or reared from this plant should be very carefully host associated and the fact reported.

Erynnis persius (Scudder)
Persius dusky wing

Erynnis persius: Klots 1951:226.

This species may occur at least rarely in the state, a belief shared by Burns (personal communication). *E. persius* itself is separable from the other two members of its species group (*E. lucilius* and *E. baptisiae*) by fairly recognizable morphological characters of the adult, and in addition is oligophagous in comparison with the highly restrictive host specificity of the other two species. The records of "*persius*" by French (1879) and Worthington (1880) are almost certainly based upon confusion with the other members of the group, probably *E. baptisiae.* Burns (1964) stated that *E. persius* is strictly univoltine (May-July) in the eastern portions of its range.

Thorybes confusis Bell
Confused cloudy wing

Thorybes confusis: Klots 1951:213.

Klots gave the range of *confusis* as "Florida to Texas n. to Kansas, Missouri, and Maryland." It may occur in southern Illinois. The record by Cushing (1970) of *confusis* from Madison County was based on misidentified material.

Urbanus proteus (Linnaeus)
Long tailed skipper

Urbanus proteus: Klots 1951:207.

Klots indicated that the northward distribution of this species in the Mississippi Valley is uncertain; since it has been recorded from several northward localities as a casual, it may occur in southern Illinois.

PAPILIONIDAE

Papilio palamedes Drury
Palamedes swallowtail

Papilio palamedes: Klots 1951:178.

This species may rarely stray northward as far extreme southern Illinois. Klots said, "In Mississip Valley uncommon, n. to Missouri (rare)." Mather Mather (1958) considered it "rare" in northern Miss sippi.

PIERIDAE

Pieris virginiensis Edwards
West Virginia white

Pieris virginiensis: Worthington 1880:47; Klots 195 201.

Although the species was listed by Worthington,

doubt that it has ever occurred in Illinois and believe that Worthington confused *P. napi oleracea*, or possibly even spring specimens of *P. rapae* with this species.

Phoebis agarithe (Boisduval)
Large orange sulphur

Phoebis agarithe: Klots 1951:191.

This butterfly was listed by Klots as straying north to Illinois.

Kricogonia lyside (Godart)
Lyside

Kricogonia lyside: Klots 1951:194.

The statement for the preceding species applies to this one as well.

RIODINIDAE

Calephelis borealis (Grote & Robinson)
Northern metalmark

Charis borealis: Worthington 1880:48.
Lephelisca borealis: Klots 1951:123.

We believe that Worthington's record of *Charis borealis* referred to *C. muticum*, then unrecognized as a separate species, but true *C. borealis* may also occur in Illinois. We have taken it in some numbers as far west as Howard County, Indiana, and it has been reported also from Montgomery County, Indiana, even closer to Illinois. McAlpine (1971) recorded it from Missouri.

LYCAENIDAE

Phaeostrymon alcestis (Edwards)
Alcestis hairstreak

Strymon alcestis: Klots 1951:135.

A report of this species from Carbondale, Jackson County, obtained during this project could not be verified. Its occurrence as a casual as far east as Illinois, however, seems possible.

Satyrium boreale (Lafontaine)

This species was recently described (Lafontaine 1969, 1970 [Two dates because name was validated in error and was redescribed.]). It was not practical to re-examine all Illinois *falacer* to check the possible presence of the new species among them, but in view of its reported occurrence in Michigan, Ohio, and Pennsylvania, it may be found in Illinois as well. The most conspicuous superficial distinction between *boreale* and *falacer* is the reduction of the subterminal line on the underside of both wings in *boreale*. On the primaries, this usually consists only of two spots between veins M_3 and Cu_2; on the secondaries, it is reduced or absent above vein M_3. There are apparently good genitalic distinctions also (Lafontaine 1970:84-85).

Callophrys augustinus (Westwood)
Brown elfin

Incisalia augustinus: Klots 1951:146.

The range of this species as given by Klots was "Newfoundland w. to Manitoba, s. to Virginia, West Virginia, Illinois, and Michigan." It probably occurs locally in the state. It was listed by French (1879), but Worthington (1880) doubted its presence in Illinois.

Lycaena epixanthe (Boisduval & Le Conte)
Bog copper

Lycaena epixanthe: Klots 1951:152.

Klots included northern Indiana and "(?) Iowa" in the range of *epixanthe*. Blatchley (1891) recorded it as "rare" in Lake County, Indiana. However, Masters & Masters (1969) rejected this record, suggesting that Blatchley's records may have been of *L. helloides*, which he did not list. According to Klots, *epixanthe* is strongly restricted to "acid bogs where the food plant, Cranberry, grows." Jones & Fuller (1955) recorded cranberry (*Oxycoccus*) from bogs in McHenry, Lake, Cook, and Will counties. The well-known Volo bog in Lake County is an acid tamarack bog, and the occurrence of *epixanthe* there seems theoretically possible. *L. epixanthe* was listed by French (1879), but Worthington (1880) doubted its occurrence in Illinois.

Plebeius saepiolus (Boisduval)
Saepiolus blue

Plebeius saepiolus: Klots 1951:167.

Klots gave the range of *saepiolus* as "all of southern Canada, s. into Iowa, Minnesota, Michigan, and Maine" and stated that the species is extending its range. He suggested that it may continue to do so southward, in which case it might in time reach as far south as northern Illinois.

NYMPHALIDAE

Limenitis archippus floridensis Strecker

Limenitis archippus floridensis: Klots 1951:115.

This butterfly was listed by Blatchley (1891) from "Illinois," without authority or further information. Possibly an unusually dark individual variant of this clinal species was so determined.

Phyciodes phaon (Edwards)
Phaon crescent

Phyciodes phaon: Klots 1951:99.

P. phaon was recorded by P. S. Remington (1956) as having been taken in St. Louis County, Missouri, and he told us (personal communication) that he saw no reason why it should not occur in Illinois. Klots gave its

range as "Florida to Texas, n. to Georgia and Kansas; s. into Mexico."

Heliconius charitonius (Linnaeus)
Zebra

Heliconius charitonius: Klots 1951:82.

Although it would appear highly unlikely that this subtropical species might occur in Illinois, Dr. L. J. Paulissen informed us (personal communication) that he had heard of the capture of a specimen on the campus of Purdue University, Lafayette, Indiana. Klots listed it as "straying n. to Kansas."

Dryas julia (Fabricius)
Julia

Dryas julia: Klots 1951:83.

Of this likewise subtropical form, Paulissen (personal communication) said, "A fair possibility for Illinois. There are Arkansas and Missouri records."

ERRONEOUS RECORDS

Some species which have been attributed to the Illinois fauna in error are discussed elsewhere in this paper. In addition to those, the following apparently erroneous records merit brief discussion.

In the Illinois Natural History Survey collection are two specimens of *Lycaena heteronea* Boisduval labeled "Centralia, Illinois, July 4 and July 29, 1893," and three examples of *Speyeria mormonia eurynome* (Edwards) with labels reading "N. Evanston, Ill. A. J. S." and dates of July 27 and July 28, 1893, and August 3, 1896. All these specimens are from A. J. Snyder of Evanston. He is known to have collected both in southern Illinois and in the western states at these periods, and it is almost certain that he took these specimens in the West and inadvertently mixed them with Illinois material or mislabeled them. We exclude these species from the Illinois list.

French (1879) listed *Grapta satyrus* and *G. gracilis* from Illinois. The basis for his inclusion of these species is unknown, but we doubt their presence in this state. The records may have been founded on misidentified material, or, less probably, on casual strays; Illinois seems too far from the range of these Canadian Zone species for them to be accepted without question.

LITERATURE CITED

In the citations of original descriptions, the true date of publication is cited in every case. If the date falls within the period of publication of a work which appeared over an extended period of time, the publication referred to is that whose publication dates encompass the date quoted. In the case of the three works of Jacob Hübner, which appeared nearly simultaneously, this procedure is obviously inapplicable; here, we have given first the initial year of the reference in quotation marks, followed by the true date of publication of the name in brackets. Where a work appeared in more than one volume, the pagination of which recommenced with "1" with each volume instead of being consecutive, we have given the volume number in parentheses following the year of description, e.g. "Cramer 1777(2):4."

Some of the names proposed by Cramer, Stoll, and Drury must be dated from the appearance of the indices to their works. For the sake of brevity in these cases, we have given the page references to the text descriptions, but have dated the names from the indices.

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Fig. 1.—Column 1 (top to bottom): *Amblyscirtes aesculapius* ♂, Pine Hills, September 1, 1966; *Euphyes bimacula* ♂, Palos Park, June 22, 1913; *Euphyes bimacula* ♀, NE Beaverville, Iroquois Co., June 28, 1966; *Hesperia ottoe* ♀, Mason State Forest near Forest City, Mason Co., July 19, 1963; *Hesperia leonardus* ♂, Danville, August 24, 1968.

Column 2 (top to bottom): *Amblyscirtes carolina* ♀, Pine Hills, September 1, 1966; *Poanes massasoit* ♀, 2 mi. NE Beaverville, Iroquois Co., June 29, 1965; *Poanes hobomok* ♀, form *pocahontas,* Palos Park, June 15, 1940; *Poanes viator* ♂, neotype, Goose Lake Prairie, Grundy Co., July 28, 1969; *Thymelicus lineola* ♂, Chicago Ridge, June 20, 1966.

Column 3 (top to bottom): *Euphyes dion* ♂, 3 mi. NW Palos Park, July 8, 1966; *Euphyes dion* ♀, Winnetka, July 28, 1958; *Problema byssus* ♀, Streator, July 20, 1964; *Erynnis baptisiae* ♂, Willow Springs, August 5, 1966, (det. H. A. Freeman); *Nastra lherminier* ♀, Danville, August 20, 1967.

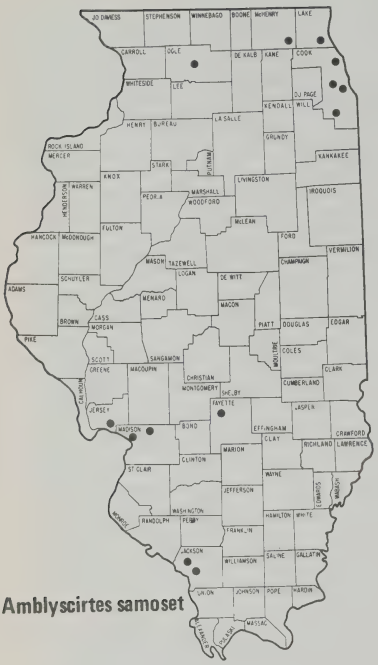
Column 4 (top to bottom): *Euphyes dukesi* ♂, Karnak, Pulaski Co., September 2, 1924; *Euphyes dukesi* ♀, Pine Hills, August 31, 1969; *Autochton cellus* ♀, Pine Hills, July 26, 1966.

Fig. 2.—Column 1 (top to bottom): *Eurema mexicana* ♂, Riverside, October 13, 1910; *Glaucopsyche lygdamus couperi* ♂, Palos Park, May 18, 1924; *Leptotes marina* ♀, Forest View, August 18, 1933; *Lycaeides melissa samuelis* ♂, "N. Ill." (Bolter collection); *Lycaeides melissa samuelis* ♀, "N. Ill." (Bolter collection).

Column 2 (top to bottom): *Callophrys polios* ♀, Illinois Beach State Park, Waukegan, May 18, 1966; *Panthiades m-album* ♂, Pontiac, July 1879; *Lycaena xanthoides dione* ♂, Streator, June 27, 1966; *Lycaena xanthoides dione* ♀, *ex* larva, Chicago, June 27, 1951; *Callophrys henrici* ♀, Putnam Co., April 13, 1958.

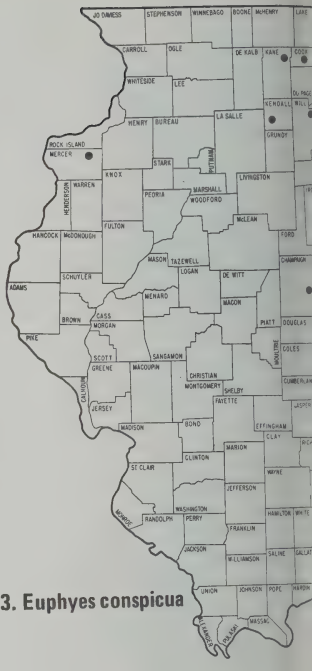
Column 3 (top to bottom): *Euchloe olympia* ♂, Illinois Beach State Park, Waukegan, May 18, 1965; *Chlosyne harrisii* ♂, Elgin, June 21,

Fig. 3.—Column 1 (top to bottom): *Euptychia gemma* ♂, underside, Pine Hills, August 18, 1966; *Euphydryas phaeton ozarkae* ♂, Giant City State Park, May 30, 1965; *Lethe creola* ♂, Pine Hills, September 1, 1966.
Column 2 (top to bottom): *Agraulis vanillae* ♂, Centreville, St. Clair Co., September 2, 1966; *Limenitis arthemis* ♀, intermediate between *L. a. arthemis* and *L. a. astyanax,* Streator, August 19, 1946.
Column 3 (top to bottom): *Cercyonis pegala olympus* ♂, Willow Springs, June 26, 1921; *Cercyonis pegala olympus* ♀, Riverside, August 20, 1908; *Cercyonis pegala* ♀, yellow-banded phase resembling *C. p. alope,* Perryton Township, Mercer Co., July 1, 1952.



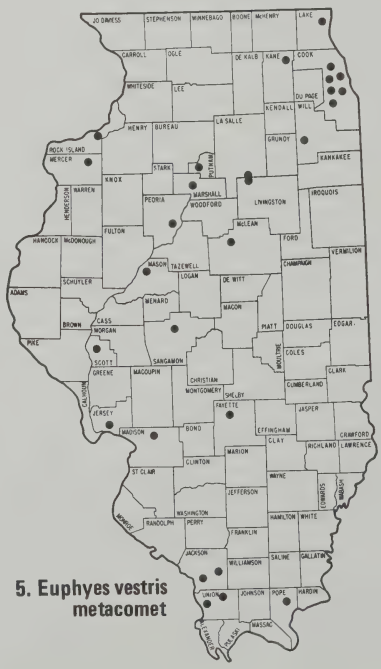
1. Amblyscirtes samoset

2. Amblyscirtes vialis

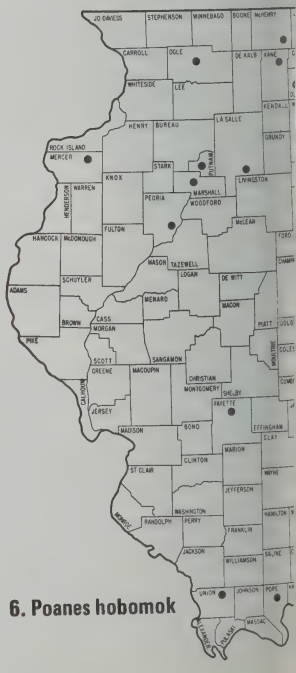


3. Euphyes conspicua

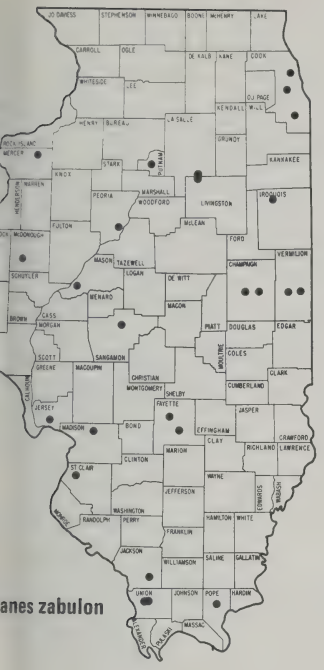
4. Euphyes bimacula



5. Euphyes vestris metacomet

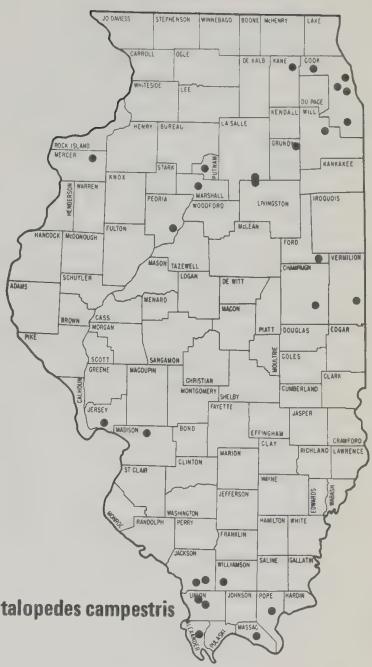


6. Poanes hobomok

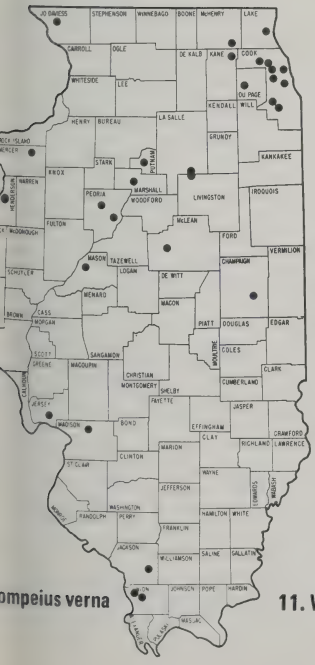


anes zabulon

8. Atrytone delaware



9. Atalopedes campestris



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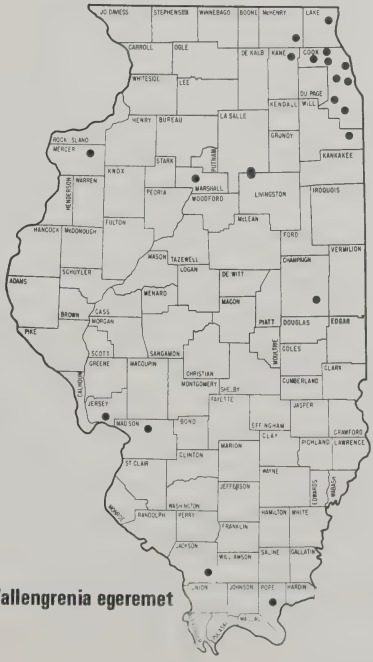
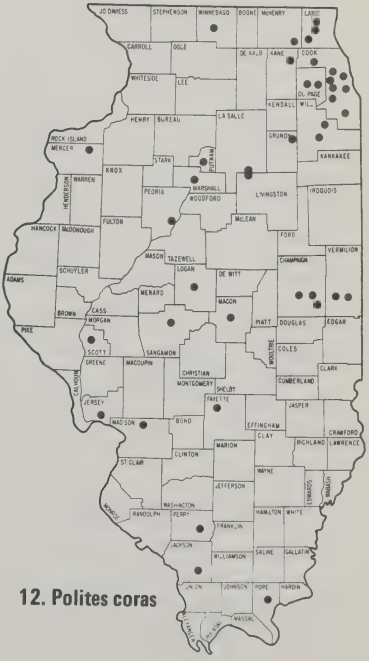
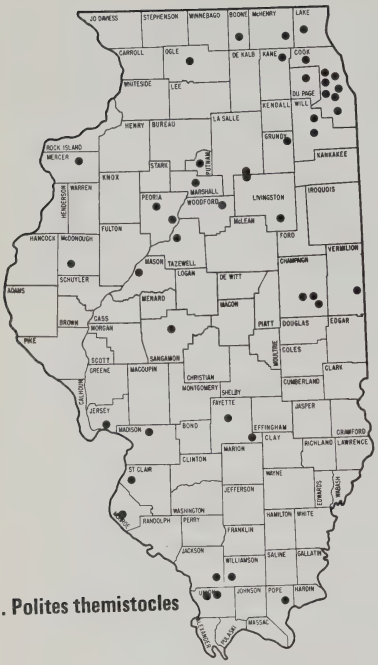


11. Wallengrenia egeremet



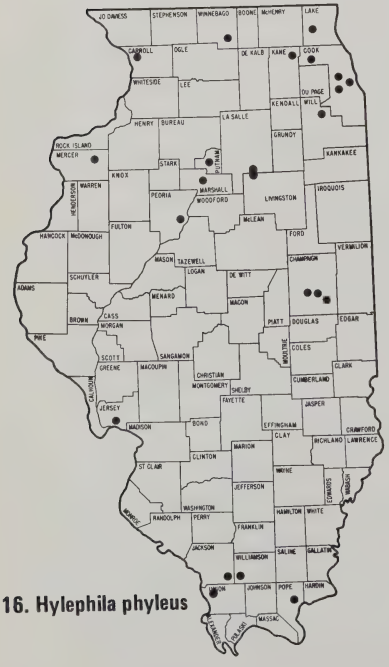
12. Polites coras



13. Polites themistocles

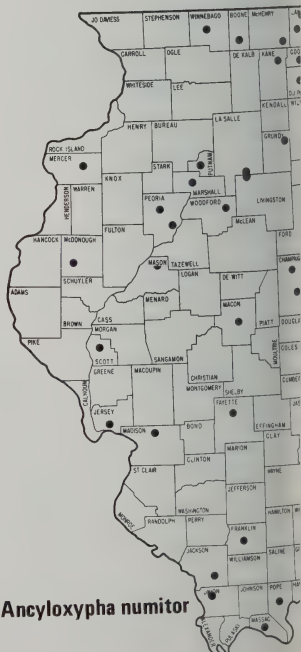
14. Polites origenes

15. Polites mystic



16. Hylephila phyleus

17. Thymelicus lineola



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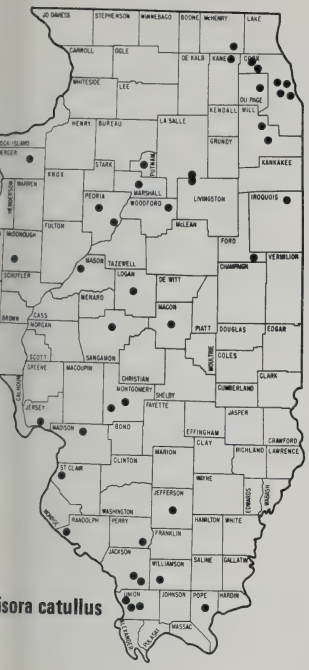
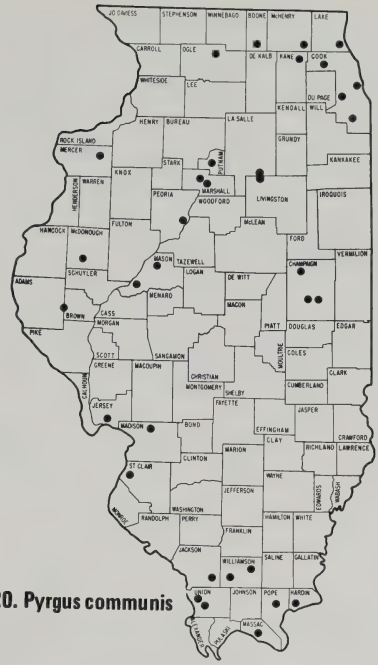


isora catullus



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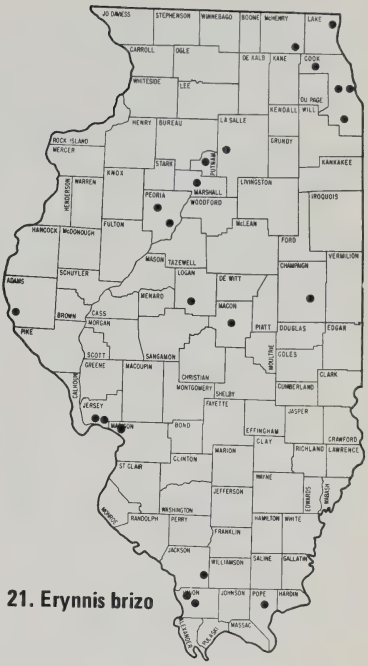
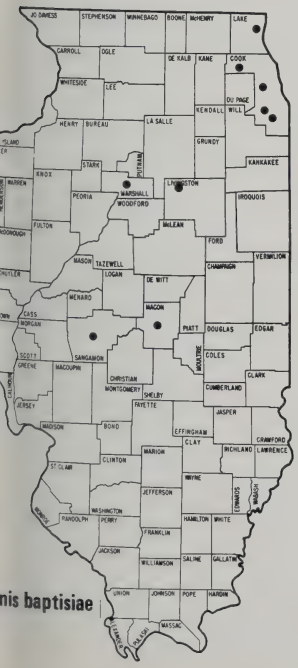


21. Erynnis brizo



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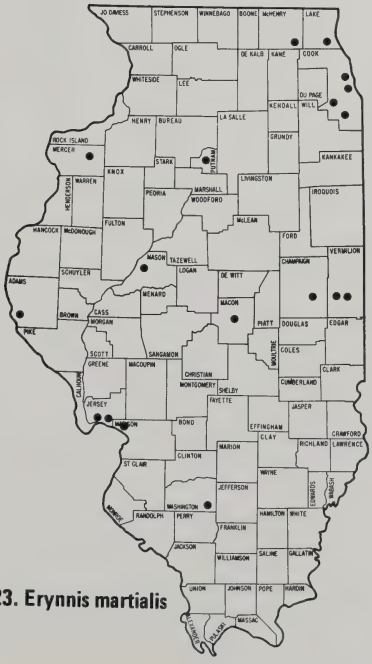

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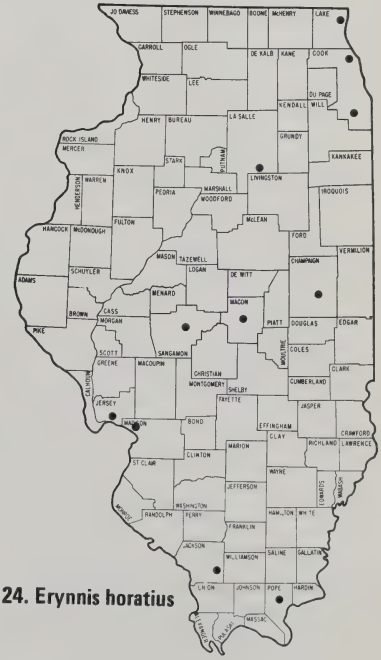

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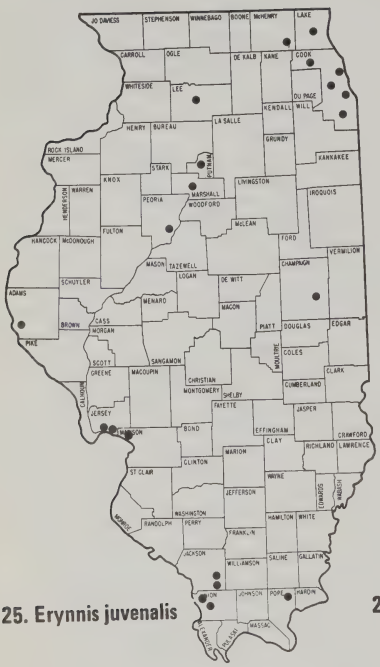

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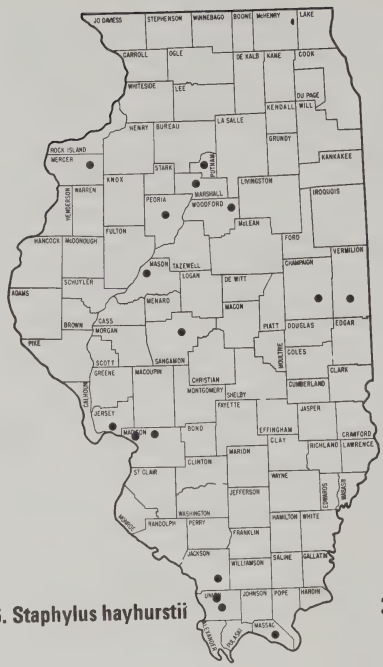
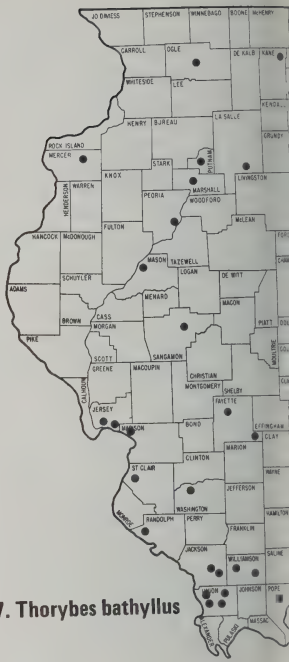
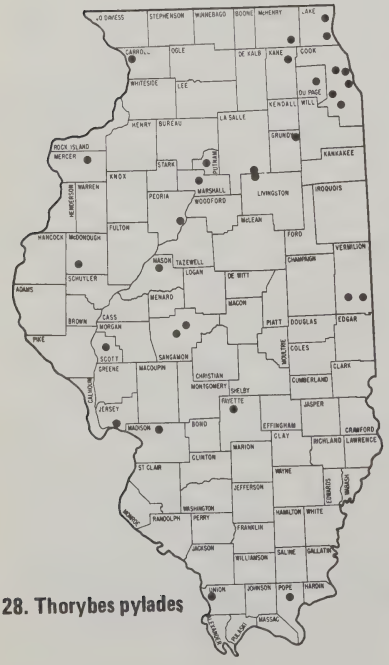


26. Staphylus hayhurstii

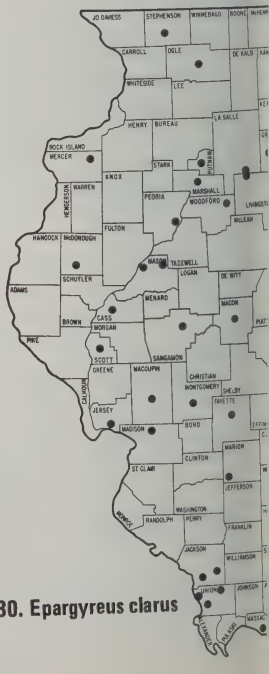


27. Thorybes bathyllus

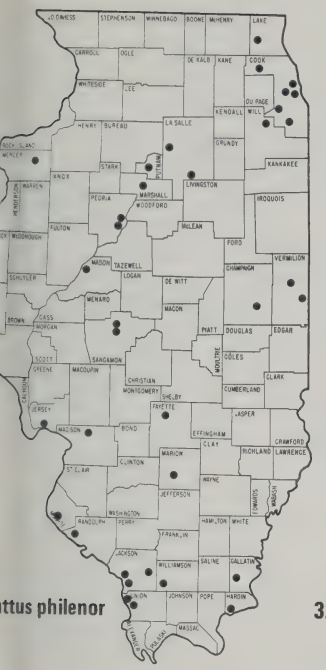


28. Thorybes pylades

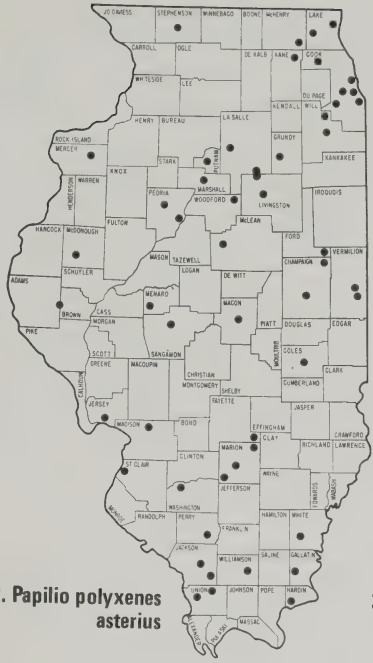
29. Achalarus lyciades



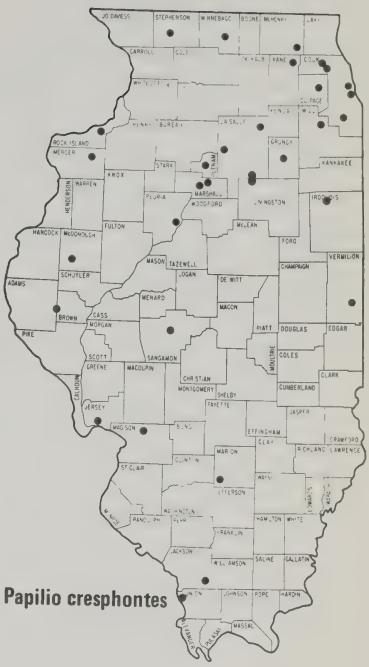
30. Epargyreus clarus



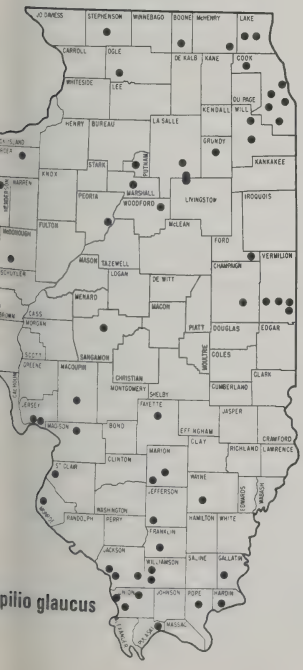
ttus philenor



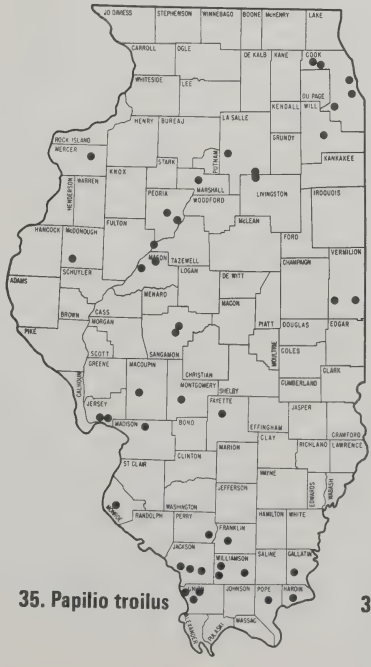
32. Papilio polyxenes asterius



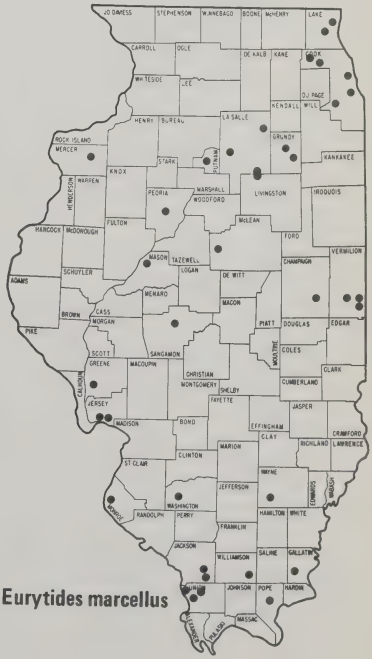
33. Papilio cresphontes



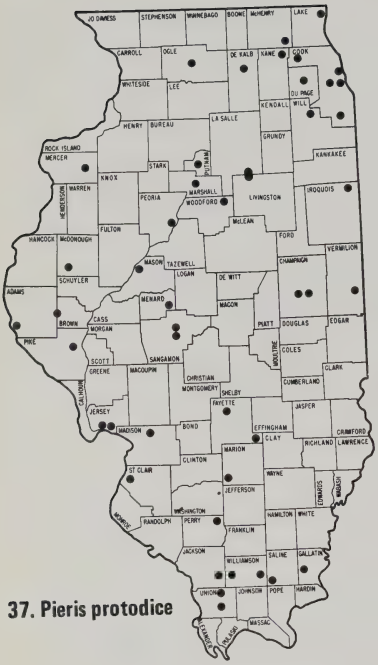
pilio glaucus



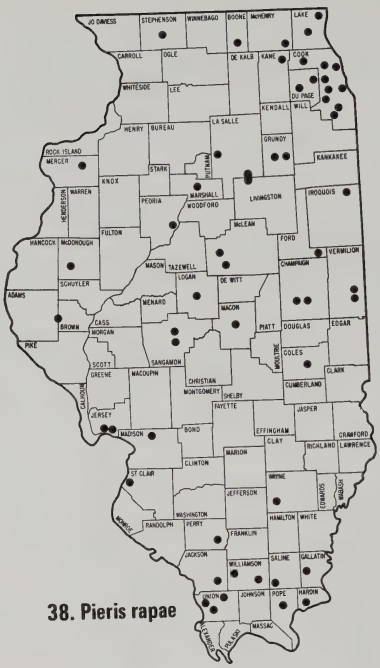
35. Papilio troilus



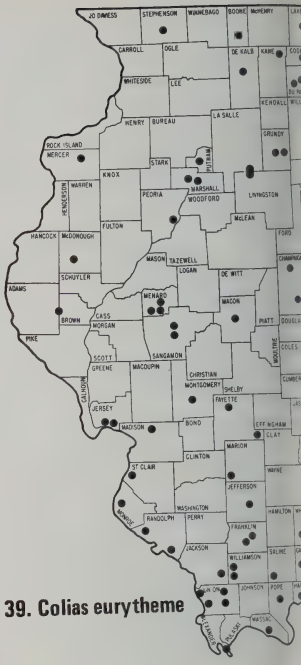
36. Eurytides marcellus



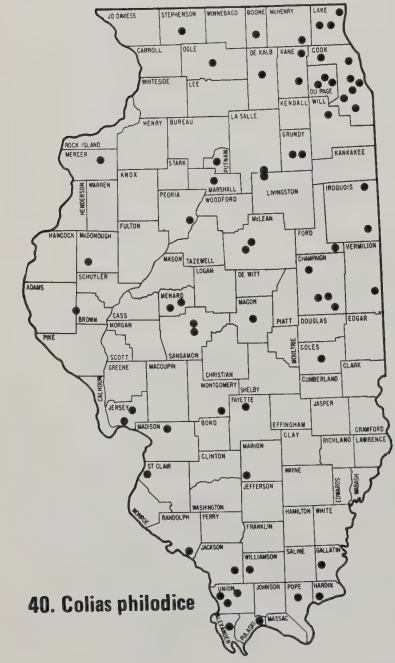
37. Pieris protodice



38. Pieris rapae



39. Colias eurytheme



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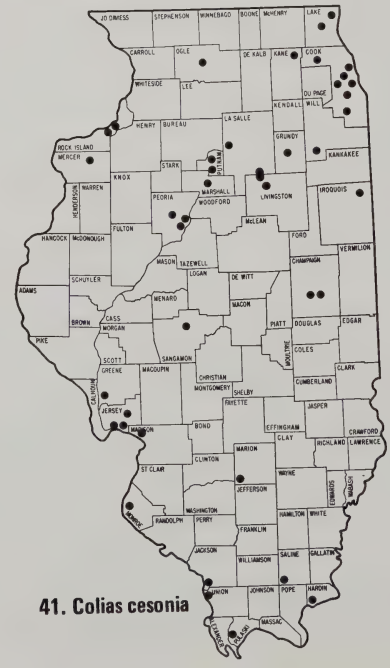
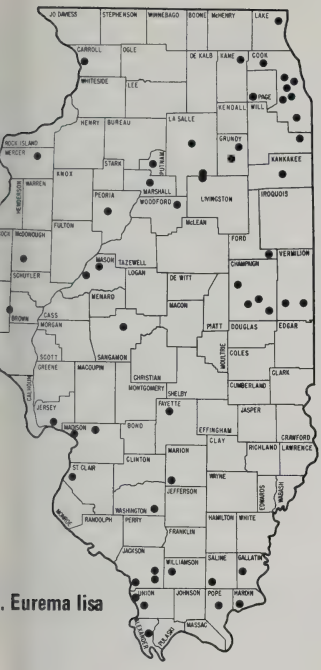


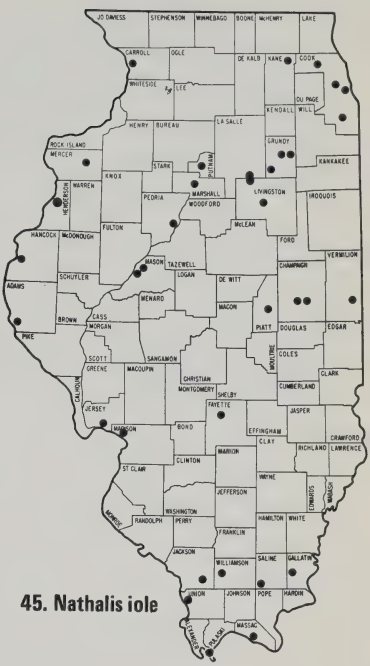
41. Colias cesonia

42. Phoebis sennae eubule

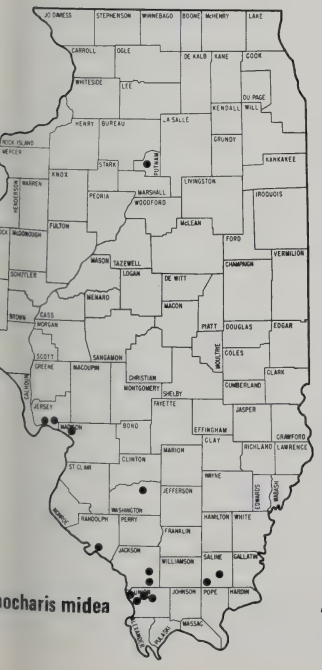


. Eurema lisa

44. Eurema nicippe



45. Nathalis iole



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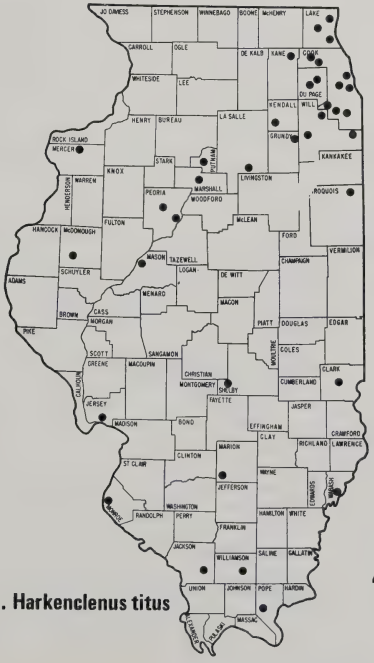
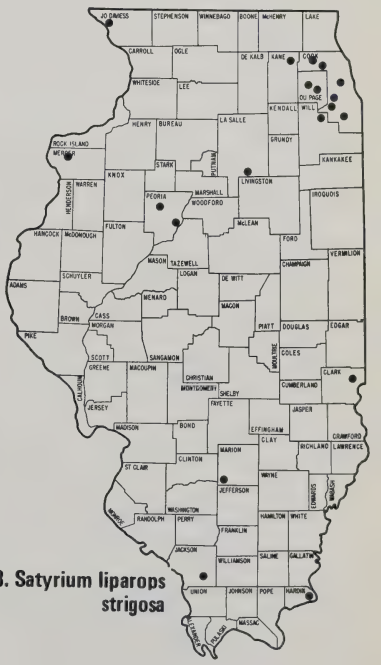
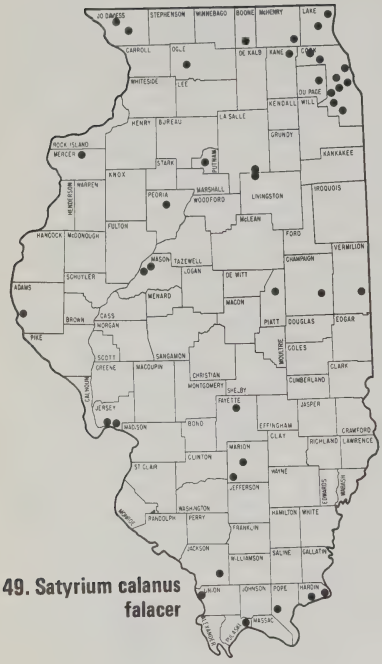


47. Harkenclenus titus



48. Satyrium liparops strigosa

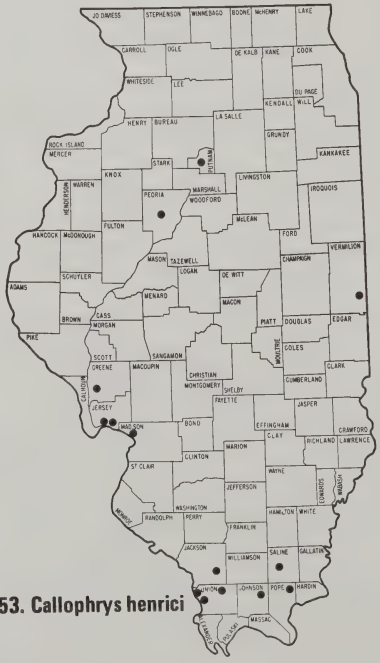


49. Satyrium calanus falacer

50. Satyrium edwardsii

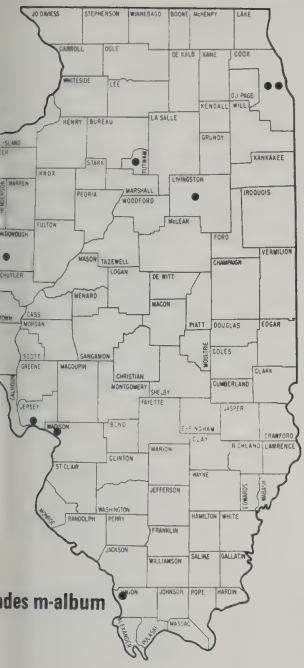
51. Satyrium acadica

52. Calycopis cecrops



53. Callophrys henrici

54. Callophrys gryneus



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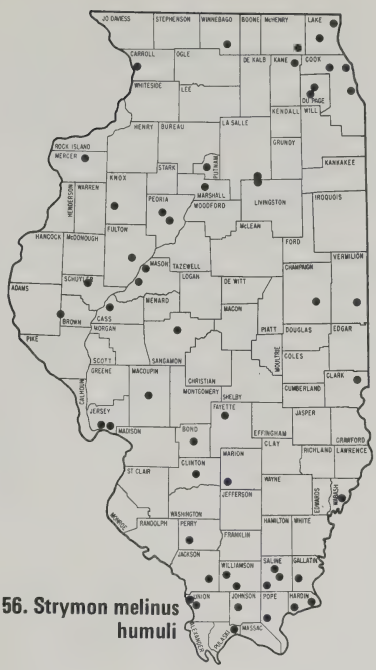
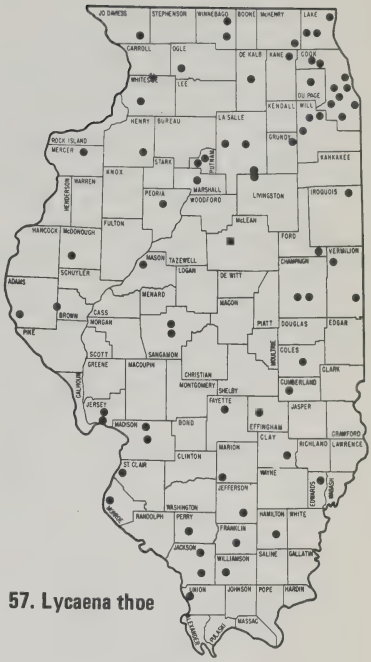
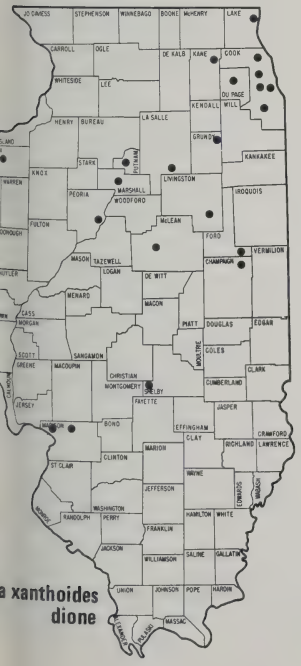


56. Strymon melinus humuli

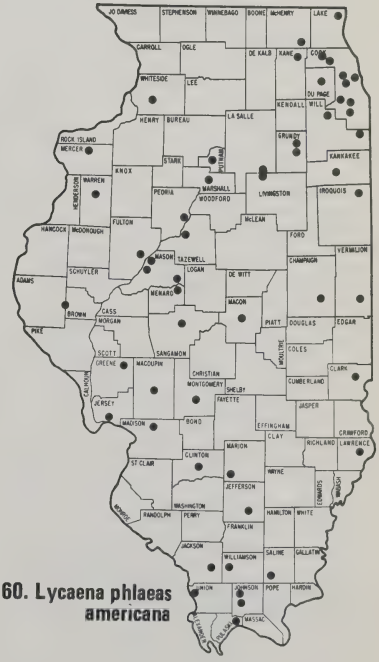


57. Lycaena thoe



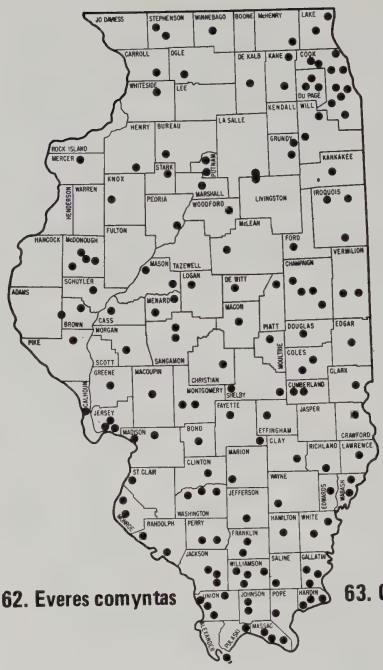
a xanthoides dione

59. Lycaena helloides



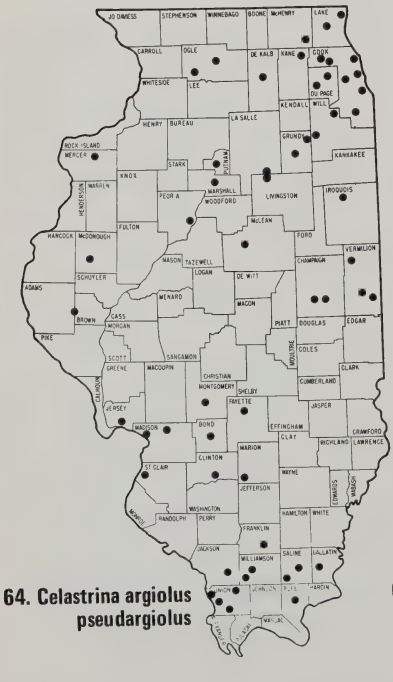
60. Lycaena phlaeas americana

61. Hemiargus isola

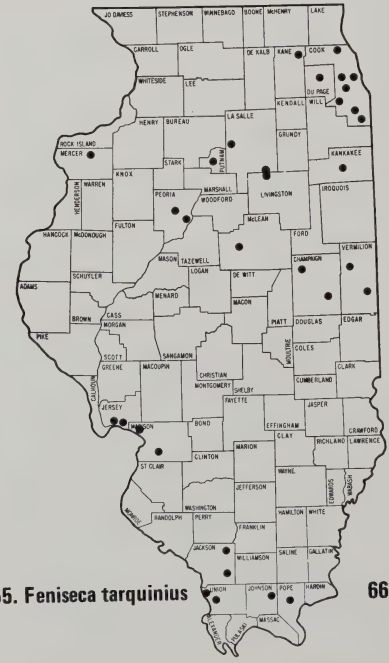


62. Everes comyntas

63. Glaucopsyche lygdamus couperi

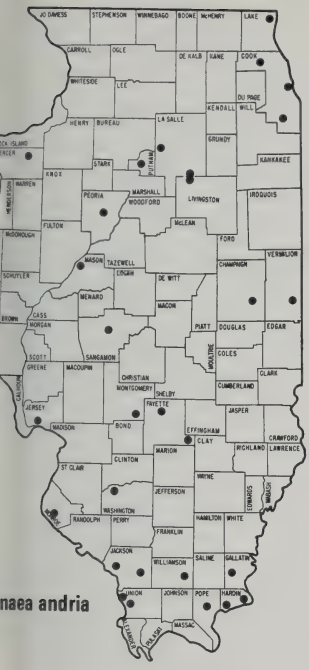


64. Celastrina argiolus pseudargiolus

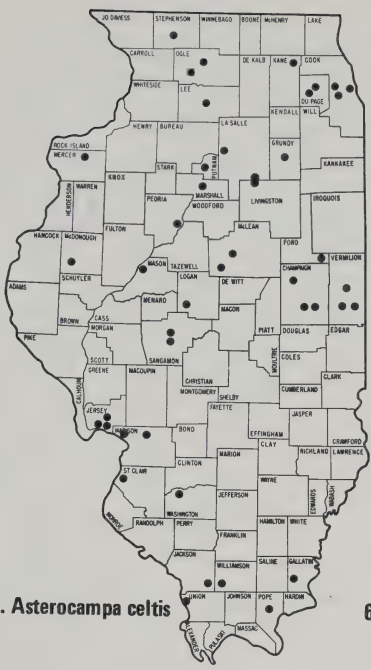


65. Feniseca tarquinius

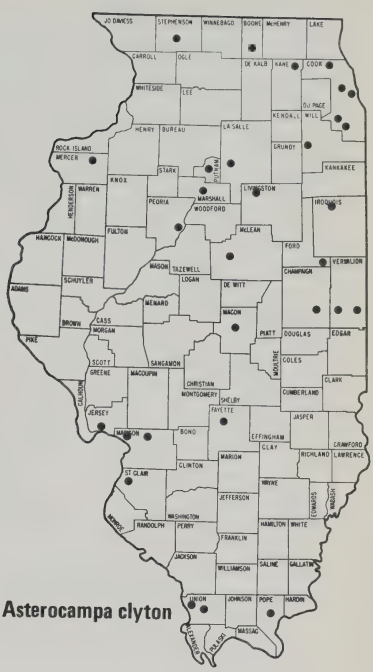
66. Libytheana bachmanii



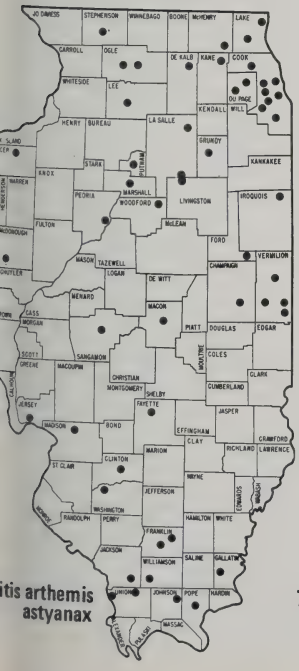
naea andria



68. Asterocampa celtis



69. Asterocampa clyton



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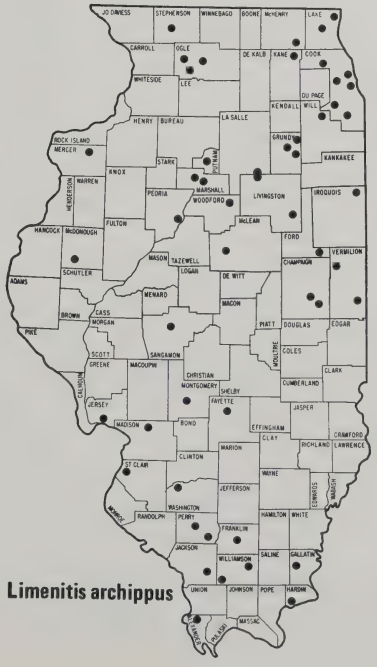
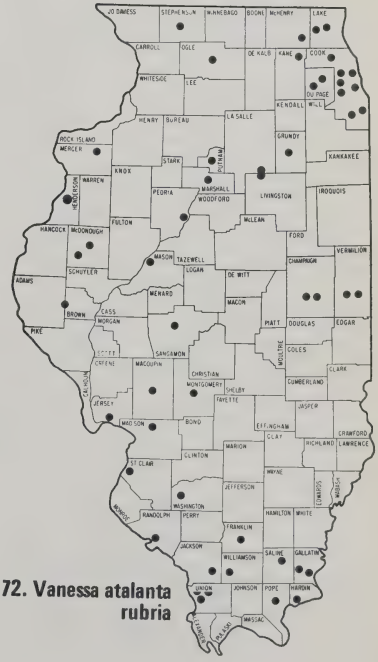
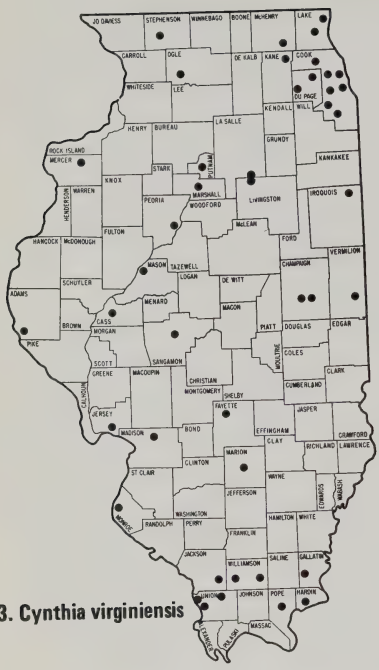


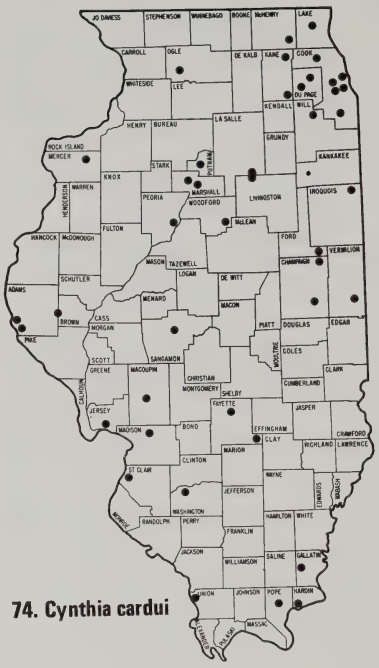
71. Limenitis archippus



72. Vanessa atalanta
rubria



73. Cynthia virginiensis



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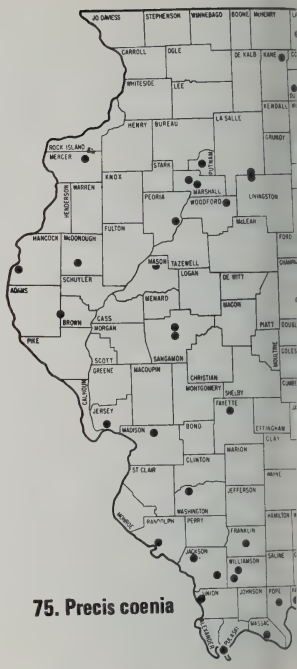

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76. Nymphalis vau-album
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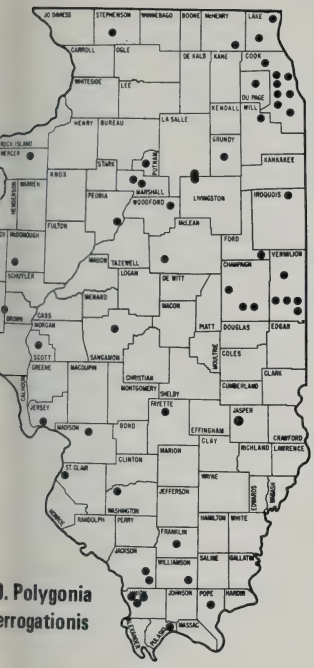
77. Nymphalis milberti

78. Nymphalis antiopa



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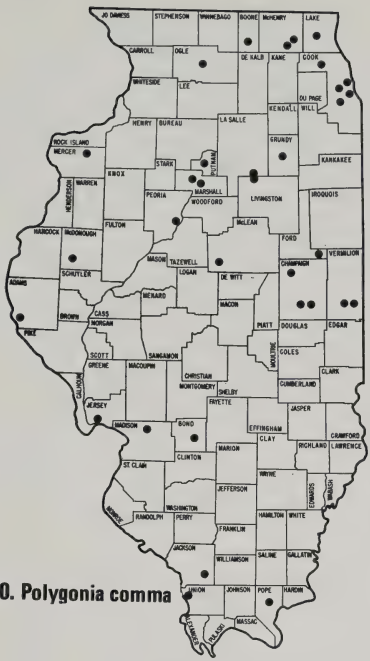

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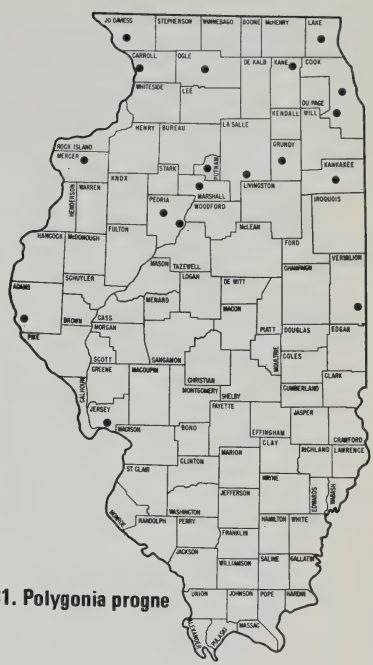

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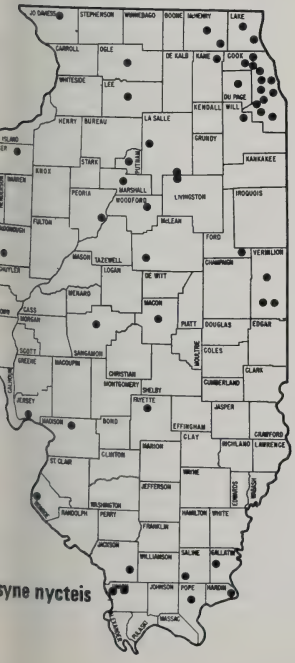

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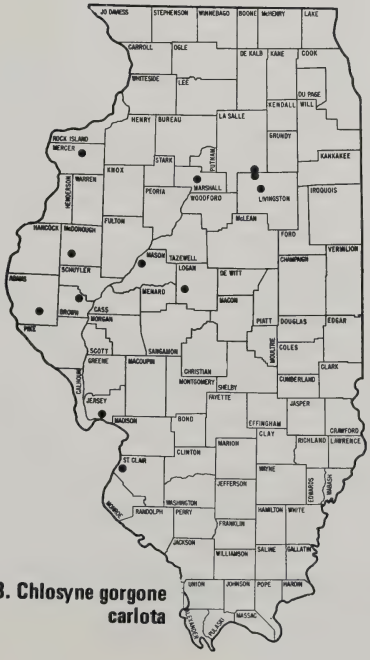

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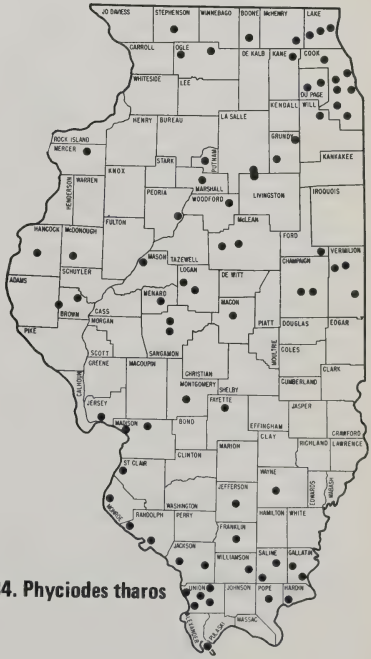

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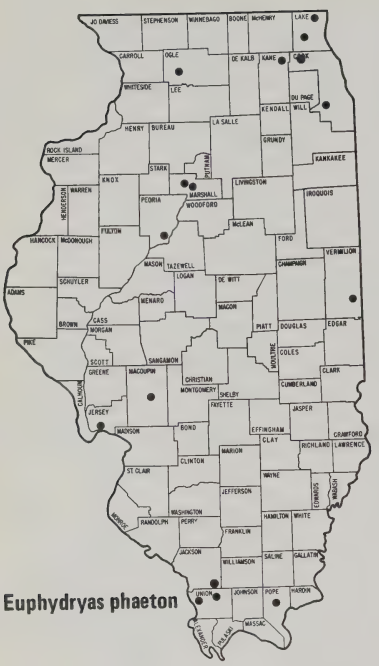

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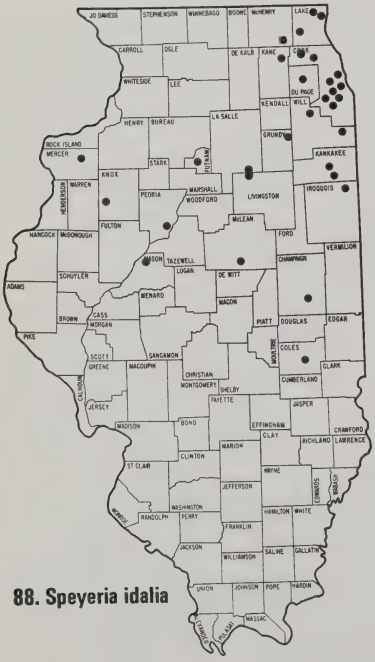
86. Boloria selene myrina

87. Boloria bellona



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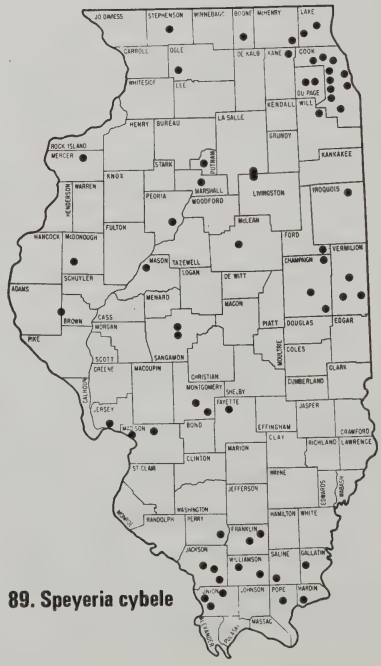
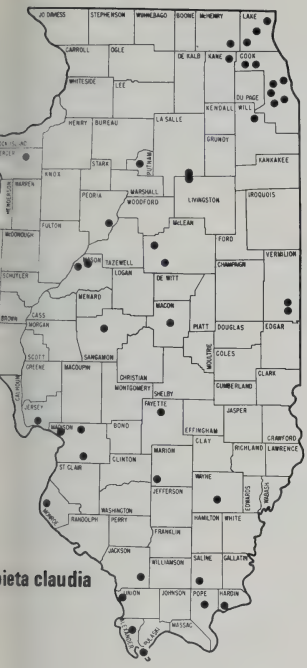


89. Speyeria cybele

90. Speyeria aphrodite



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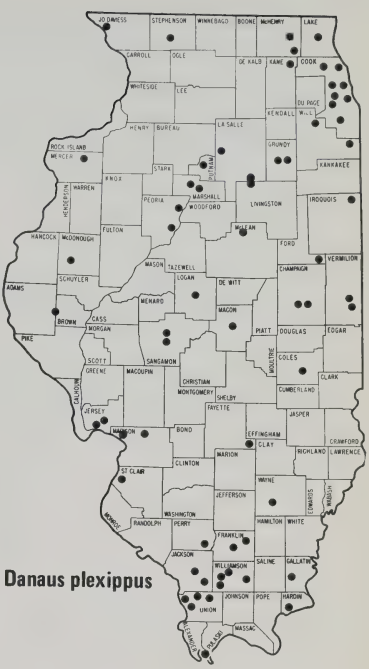

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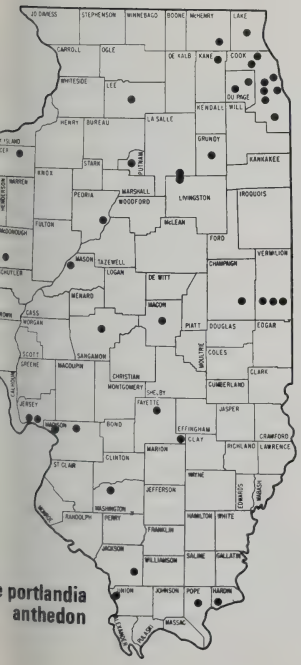
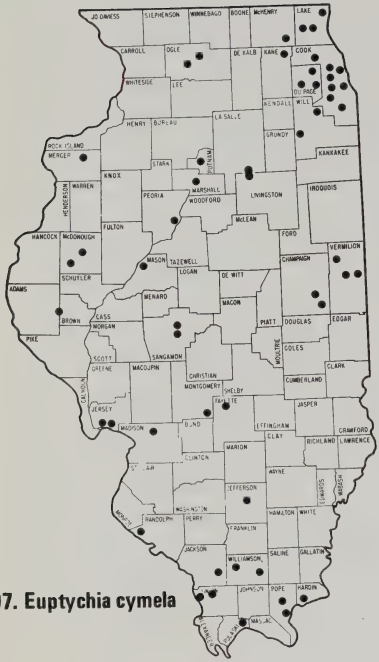


e portlandia anthedon

95. Lethe eurydice

96. Euptychia gemma



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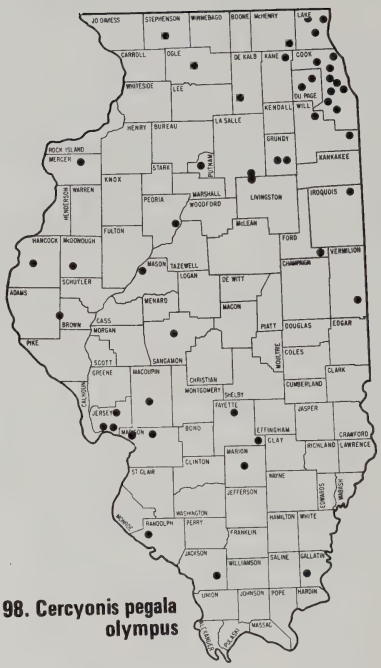

98. Cercyonis pegala olympus

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Biological Notes No. 82

Lactate Dehydrogenase Isozymes of Darters and the Inclusiveness of the Genus *Percina*

Lawrence M. Page
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Lactate Dehydrogenase Isozymes of Darters and the Inclusiveness of the Genus *Percina*

Lawrence M. Page and Gregory S. Whitt

The darters (Etheostomatini), with over 110 recognized species, comprise the second largest group of North American freshwater fishes. At present, the most widely accepted classification of darters is a proposal of Bailey progressively formulated in Bailey (1951), Bailey et al. (1954), and Bailey & Gosline (1955).

The latter paper lists three darter genera *(Percina, Ammocrypta, Etheostoma)* and 22 subgenera and arranges them according to evolutionary advancement. This classification is based on years of study by Bailey and reflects to a high degree the true relationships among the darters. However, little documentation was presented in the 1955 paper, and little has been presented subsequently, for the classification. Thus some of the groupings and arrangements deserve closer scrutiny.

Collette (1965) compared breeding tubercle patterns among all darters and used the same genera and subgenera as had Bailey & Gosline except for the recognition of *Villora* as an additional subgenus of *Etheostoma*. More recently *Doration* and *Vaillantia* have also been recognized as valid subgenera of *Etheostoma* (Cole 1967, Howell 1968).

Systematic studies of darters have been mainly descriptions of species. Few attempts have been made to elucidate relationships among species. Although recent descriptions of new species include remarks on similarities between the *species novum* and the assumed closest relatives, they seldom contain analyses involving more than two or three species.

A controversial aspect of Bailey's classification has been the acceptance of the genus *Percina*. Some ichthyologists believe *Percina caprodes* and its closest relatives *P. rex, P. burtoni* and *P. macrolepida* deserve separate generic status and assign the remaining species to *Hadropterus* (Hubbs & Lagler 1958, Hubbs 1967, Minckley 1963, Stevenson 1971, Winn 1958) or to *Hadropterus* and *Cottogaster* (Curd 1967).

The decision to combine the species of *Percina* and *Hadropterus* in the same genus was based primarily on the ubiquitous presence of modified (enlarged and strongly toothed) scales on the breasts of males of all species in both groups (Bailey et al. 1954). Darters in other genera do not have the modified scales.

Data are herein presented on another characteristic that is seemingly ubiquitous among, and nearly unique to, the species of *Percina*. The characteristic is the electrophoretic mobility of a readily distinguishable homopolymeric lactate dehydrogenase (LDH) isozyme. The presence of a unique morphological characteristic and a nearly unique enzymatic characteristic among species of *Percina* is considered strong evidence of a monophyletic origin, attests to the genetic continuity of the group, and strongly supports relegation of *Hadropterus* to the synonymy of *Percina*.

. . . . . .

We appreciate the assistance of Jerry F. Howell, Hartley F. Hutchins, John C. Marlin, Michael P. Marlin, Douglas W. Schemske, Philip W. Smith, Richard L. Smith, Lewis J. Stannard, John A. Tranquilli, and Donald W. Webb in collecting specimens for this study. Dr. Smith also reviewed and offered helpful comments on the manuscript.

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METHODS AND MATERIALS

The head of each darter was homogenized by hand in two volumes of tris-HCl buffer (0.1 M, pH 7.0) at 4°C. The homogenates were centrifuged for 30 minutes in a Sorvall RC2-B centrifuge at 4°C at 48,200 *g*. The supernatant was recentrifuged under the same conditions. The final supernatant fraction was immediately subjected to starch gel electrophoresis. The immunochemical procedure was described in Whitt (1970).

Vertical starch gel electrophoresis (Büchler instruments) was accomplished in a 14 percent gel at 8V/cm for 16-20 hours at 4°C. Two different buffer systems were employed. The tris-citrate pH 6.8 stock buffer contained 0.75 M tris and 0.25 M citric acid (monohydrate). Dilution of the stock buffer for both electrode chambers was 1:7 and for the gel it was 1:20. The EBT stock buffer contained EDTA (tetrasodium, 1×10^{-4}M), boric acid (2.5×10^{-2}M) and tris (4.5×10^{-2}M) and had a pH of 8.7. Dilutions of the stock buffer for gel, cathode chamber, and anode chamber were 1:5, 1:5, and 1:7, respectively. The staining procedure for LDH isozymes has been described in Shaw & Prasad (1970). The control for nonspecific reductants or "nonspecific dehydrogenases" was accomplished by incubating one-half of the gel in all the staining components except for the substrate, L-lactate.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from the Section of Faunistic Surveys and Insect Identification of the Illinois Natural History Survey. Dr. Lawrence M. Page is an Assistant Taxonomist at the Survey. Dr. Gregory S. Whitt is an Associate Professor of Zoology at the University of Illinois.

The LDH isozymes of 494 specimens of 68 species ere examined. Patterns of 67 species are illustrated in g. 1: *Ammocrypta (Ammocrypta) beani*: Leaf River, nes Co., Miss.; *A. (A.) pellucida*: Middle Fork, Ver- ilion Co., Ill.; *Etheostoma (Allohistium) cinereum*: g South Fork, Scott Co., Tenn.; *E. (Boleosoma) longi- anum*: trib., James River, Botetourt Co., Va.; *E. (B.) grum*: trib., Gasconade River, Maries Co., Mo.; *E. B.) olmstedi*: Tar River, Franklin Co., N. C.; *E. Catonotus) barbouri*: Brushy Fork, Casey Co., Ky.; *E. .) flabellare*: Maries River, Osage Co., Mo.; *E. (C.) nnicotti*: Big Creek, Hardin Co., Ill.; *E. (C.) obeyense*: rguson Creek, Livingston Co., Ky.; *E. (C.) squami- ps*: Sugar Creek, Livingston Co., Ky.; *E. (C.) virgat- a*: Harpeth River, Williamson Co., Tenn.; *E. (C.) ecies*: Cypress Creek, Wayne Co., Tenn.; *E. (Doration) gmaeum*: Little River, Blount Co., Tenn.; Clarks rk, Marshall Co., Ky.; *E. (Etheostoma) blennioides*: nbarras River, Cumberland Co., Ill.; *E. (E.) histrio*: af River, Jones Co., Miss.; *E. (E.) rupestre*: Cahaba ver, Bibb Co., Ala.; *E. (E.) tetrazonum*: Gasconade ver, Maries Co., Mo.; *E. (E.) thalassinum*: trib., luda River, Pickens Co., S. C.; *E. (E.) zonale*: Gas- nade River, Maries Co., Mo.; *E. (Hololepis) gracile*: ear Creek, Union Co., Ill.; *E. (H.) serriferum*: Collie amp, Martin Co., N. C.; *E. (Ioa) vitreum*: Tar River, anklin Co., N. C.; *E. (Litocara) nianguae*: Big Tavern eek, Miller Co., Mo.; *E. (Microperca) microperca*: on Creek, Kane Co., Ill.; *E. (M.) proeliare*: Alcorn eek, Pope Co., Ill.; *E. (Nothonotus) bellum*: Brushy rk, Casey Co., Ky.; *E. (N.) camurum*: Middle Fork, rmilion Co., Ill.; *E. (N.) jordani*: Conasauga River, ıdley Co., Tenn.; *E. (N.) maculatum*: Big South Fork, ott Co., Tenn.; *E. (N.) rufilineatum*: Little River, unt Co., Tenn.; *E. (N.) tippecanoe*: Big South Fork, ott Co., Tenn.; *E. (Oligocephalus) asprigene*: Clear eek, Union Co., Ill.; *E. (O.) caeruleum*: Embarras er, Cumberland Co., Ill.; James River, Webster Co., .; *E. (O.) ditrema*: Sugar Creek, Bradley Co., Tenn.; *(O.) exile*: Otter Creek, Winnebago Co., Ill.; *E. (O.) ae*: James River, Webster Co., Mo.; *E. (O.) specta-* : Stony Creek, Vermilion Co., Ill.; *E. (O.) swaini*: f River, Jones Co., Miss.; *E. (Psychromaster) trisella*: asauga River, Bradley Co., Tenn.; *E. (Ulocentra) sae*: Sugar Creek, Bradley Co., Tenn.; *E. (U.) duryi*: ress Creek, Wayne Co., Tenn.; *E. (U.) simoterum*: le River, Blount Co., Tenn.; *E. (U.)* species A: Flat ek, Maury Co., Tenn.; *E. (U.)* species B: trib., Per- o River, Escambia Co., Ala.; *E. (U.)* species C: Clarks k, Marshall Co., Ky.; *E. (Vaillantia) chlorosomum*: ar Creek, Union Co., Ill.; *E. (Villora) edwini*: trib., dido River, Escambia Co., Ala.; *Percina (Alvordius)*[1] *sa*: Tar River, Franklin Co., N. C.; *P. (A.) macu-* : Clarks Fork, Marshall Co., Ky.; *P. (A.) peltata*: River, Franklin Co., N. C.; *P. (A.) notogramma*: , James River, Botetourt Co., Va.; *P. (A.)*[1] *roanoka*: noke River, Montgomery Co., Va.; *P. (A.)* species: asauga River, Bradley Co., Tenn.; *P. (Cottogaster) elandi*: Big South Fork, Scott Co., Tenn.; Shoal ek, Cherokee Co., Kan.; *P. (Ericosma) evides*: Gas- conade River, Maries Co., Mo.; *P. (E.) palmaris*: Conasauga River, Bradley Co., Tenn.; *P. (Hadropterus) lenticula*: Leaf River, Jones Co., Miss.; *P. (H.) nigrofasciata*: Leaf River, Jones Co., Miss.; *P. (H.) sciera* (eight specimens): Embarras River, Cumberland Co., Ill.; *P. (Hypohomus) aurantiaca*: Little Pigeon River, Sevier Co., Tenn.; *P. (Imostoma) shumardi*: Main Ditch, New Madrid Co., Mo.; *P. (I.) uranidea*: Main Ditch, Mississippi Co., Mo.; *P. (I.)* species: Conasauga River, Bradley Co., Tenn.; *P. (Percina) caprodes carbonaria*: Big Tavern Creek, Miller Co., Mo.; *P. (P.) c. caprodes* x *semifasciata*: Embarras River, Cumberland Co., Ill.; *P. (Swainia) phoxocephala*: Embarras River, Cumberland Co., Ill.; *P. (?)*[1] *cymatotaenia*: Gasconade River, Pulaski Co., Mo.

Fig. 2: *E. caeruleum*: Embarras River, Coles Co., Ill.; *E. flabellare*: Gasconade River, Pulaski Co., Mo.; *E. gracile*: Clear Creek, Union Co., Ill.; *E. nigrum*: Embarras River, Cumberland Co., Ill.; *P. caprodes*: Embarras River, Cumberland Co., Ill.; *P. cymatotaenia*: Gasconade River, Pulaski Co., Mo.; *P. maculata*: Gibbons Creek, Pope Co., Ill.; *P. phoxocephala*: Embarras River, Cumberland Co., Ill.; *P. sciera*: Embarras River, Cumberland Co., Ill.; *P. uranidea*: Main Ditch, Mississippi Co., Mo.

Fig. 4: *E. cinereum*: Little River, Blount Co., Tenn.; *E. duryi*: Cypress Creek, Wayne Co., Tenn.; *E. edwini*: trib., Perdido River, Escambia Co., Ala.; *E. flabellare*: Cypress Creek, Wayne Co., Tenn.; *E. microperca*: Coon Creek, Kane Co., Ill.; *E. proeliare*: Alcorn Creek, Pope Co., Ill.; *E. trisella*: Conasauga River, Bradley Co., Tenn.; *P. caprodes*: Maries River, Osage Co., Mo.; *P. sciera*: Leaf River, Jones Co., Miss.

RESULTS AND DISCUSSION

The suitability of electrophoretic data for assessment of evolutionary relationships among fishes has been demonstrated by Tsuyuki et al. (1965), Ohno et al. (1968), Markert & Holmes (1969), Lush et al. (1969), Koehn (1969), and Whitt & Horowitz (1970). As specific gene products, isozymes (multiple molecular forms of an enzyme, Markert & Møller 1959) are useful as taxonomic characters. The LDH isozymes of fishes have proven to be excellent gene markers (Markert & Faulhaber 1965, Goldberg 1966, Morrison & Wright 1966, Odense et al. 1969, and Whitt 1970). The following analysis includes only those isozymes formed by the assembly of LDH subunits encoded in the LDH A and B loci (Markert & Faulhaber 1965). The activity of the LDH E locus was too low to employ the retinal-specific E_4 isozyme (Whitt et al. 1971, Horowitz & Whitt 1972) as a genetic marker.

LDH patterns tended to be highly conservative. For the 494 specimens (68 species) examined, intraspecific variation was limited to infrequent polymorphism, occasional low activities of individual bands, slight geographic variation in a few species, and marked geographic variation in *Percina copelandi* (Page & Whitt 1973).

[1] Subgeneric reassignments in *Percina* are based on conclusion by the senior author (Page 1974).

Although data herein presented are expressions of only one character (the LDH isozyme pattern), they are especially significant at the generic level. The LDH B_4 isozyme of 19 species of *Percina* possessed an identical electrophoretic mobility; that mobility was absent in 45 of 46 species of *Etheostoma* and in the 2 species of *Ammocrypta* examined (Fig. 1). Although not resolved for the specimen of *P. uranidea* in Fig. 1, in a separate run using another specimen the band was as prominent in this species as in other *Percina* (Fig. 2). In addition to the 67 species presented in Fig. 1, *E. punctulatum* was examined and was without the B_4 mobility of *Percina*.

Isozymes may be selectively precipitated by the addition of antisera to the enzyme extract prior to electrophoresis. The anodal band of *Percina* (designated B_4) was precipitated by the anti-B serum but not the anti-A serum (Fig. 3) indicating that it contained only B subunits and was the B_4 homopolymer.

Electrophoresis of LDH isozymes in EBT buffer (Fig. 4) showed more clearly the unique mobilities of LDH isozymes of certain species of *Etheostoma (E. cinereum, E. microperca, E. edwini, E. trisella,* and *E. duryi)* which appeared in tris-citrate buffer (Fig. 1) to possess a band with a mobility possibly identical to that of the B_4 of *Percina* species. As demonstrated in EBT buffer, *E. cinereum* does posses a band with the same mobility as the *Percina* B_4; the other species do not. The most anodal band of *E. squamiceps* also appears in Fig. 1 to have the same mobility as the B_4 band of *Percina;* however, electrophoresis in other gels demonstrated it to be different

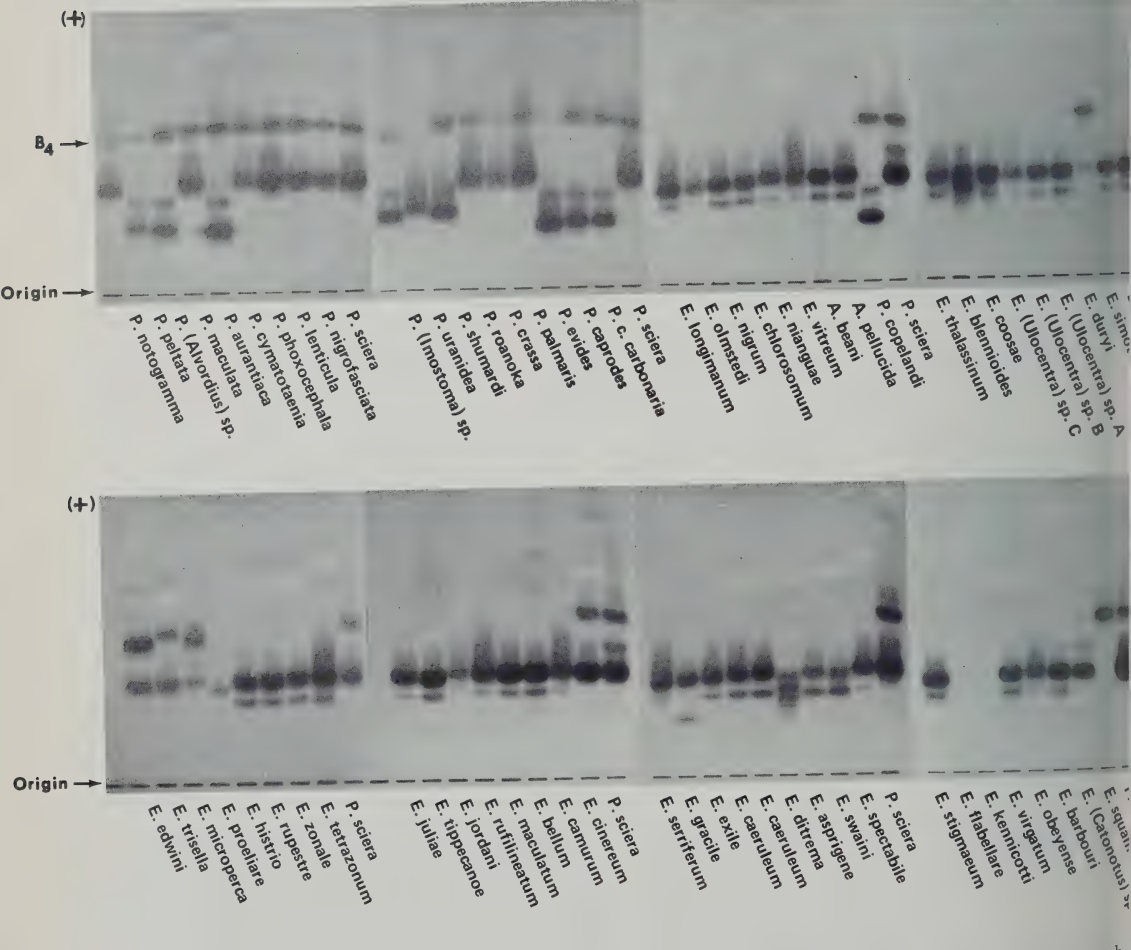

Fig. 1.—Lactate dehydrogenase isozymes from head extracts of 67 species of darters. *Percina sciera* is present on each as a marker species to facilitate comparisons between gels. Electrophoresis was in pH 6.8 tris-citrate buffer.

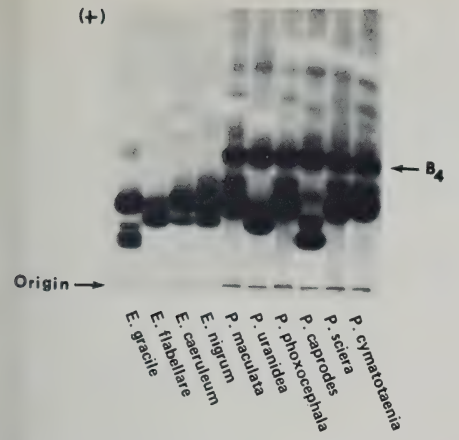

Fig. 2.—Lactate dehydrogenase isozymes of six species of *rcina* and four of *Etheostoma*. Electrophoresis was in pH 8 tris-citrate buffer.

g. 4 also shows more detailed patterns of species poorly solved in Fig. 1 *(E. flabellare* and *E. proeliare)*.

Percina characteristics—such as less elaborate spawning behavior than in *Etheostoma,* the presence of a gas adder in most species, generally larger size, and a complete lateral line—leave no doubt that this genus includes e primitive darters, and the distinctive B_4 isozyme mobility is probably an expression of genetic conservatism sent in species of the more advanced genera (except *E. ıereum*).

The genetic continuity demonstrated by the identical obility of the B_4 isozyme band in all 19 species of *rcina* examined is strong evidence of relationships ıong the species currently assigned to the genus. The species analyzed included representatives of all 8 cognized subgenera (Bailey & Gosline 1955, Collette 65).

A genus may be defined as a "monophyletic group of species, which is separated from other taxa of the same rank [other genera] by a decided gap" (Mayr 1969). The enzymatic (LDH B_4 mobility) and morphological (modified scales) evidence for a monophyletic origin for all species in *Percina* is persuasive. Although the subgenus *Percina* is quite distinct in several ways from other subgenera, to grant the subgenus *Percina* separate generic status (as suggested by Curd 1967, Hubbs & Lagler 1958, Hubbs 1967, Minckley 1963, Stevenson 1971, and Winn 1958) because of its distinctiveness from other *Percina* negates the criterion of monophyly (Hennig 1966) for the genus containing the remaining species.

If the subgenus *Percina* were to be recognized as a separate genus, it would be a monophyletic group of four species, and the remaining species presumably would be put in *Hadropterus* as outlined by Bailey (1951). Of this composition, *Hadropterus* would not include all species descended from a common ancestor (Fig. 5), and therefore would not be a valid, monophyletic genus. The subgenus *Percina* shares with most other *Percina* subgenera (*Hadropterus, Swainia, Alvordius, Ericosma, Cottogaster*) the presence of a row of modified scales on the midbelly. The row is lacking in the subgenus *Hypohomus* (Fig. 5). Since it is extremely doubtful that a midbelly row of modified scales independently evolved twice, the separation of the subgenus *Percina* from the other subgenera with the row of modified scales almost certainly occurred after the separation of the subgenus without the row *(Hypohomus)*. Therefore if *Percina* is to be a genus of four species, and genera are to be monophyletic, there also must at least be a genus *Hypohomus* and a genus *Hadropterus* (containing the subgenera *Hadropterus, Swainia, Ericosma, Alvordius, Cottogaster,* and *? Imostoma*). The morphological gaps among the species within the latter two genera are in some instances larger than that between genera, although the genera would probably be monophyletic.

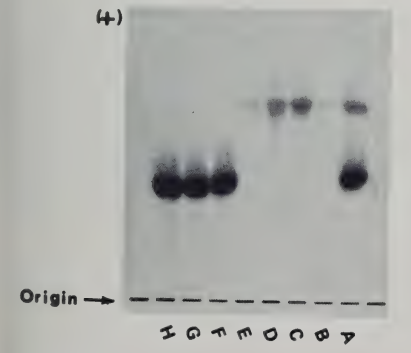

Fig. 3.—Effects of antisera on the lactate dehydrogenase ymes of *Percina sciera.* (A) untreated LDH isozymes, (B) serum alone, (C,D,E) effect of anti-LDH A serum on the *ciera* isozymes, (F,G,H) effect of anti-LDH B serum on the *ciera* isozymes. The anodal LDH band is the B_4 isozyme.

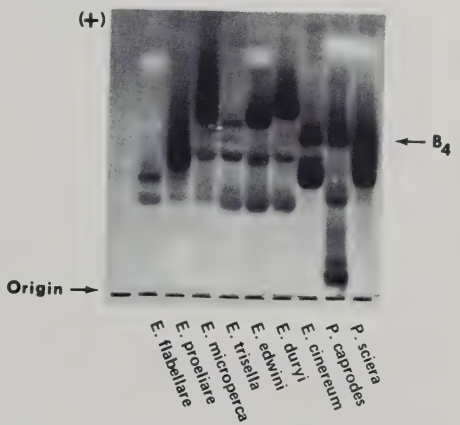

Fig. 4.—Lactate dehydrogenase isozymes of nine species of darters. Electrophoresis was in pH 8.7 EBT buffer.

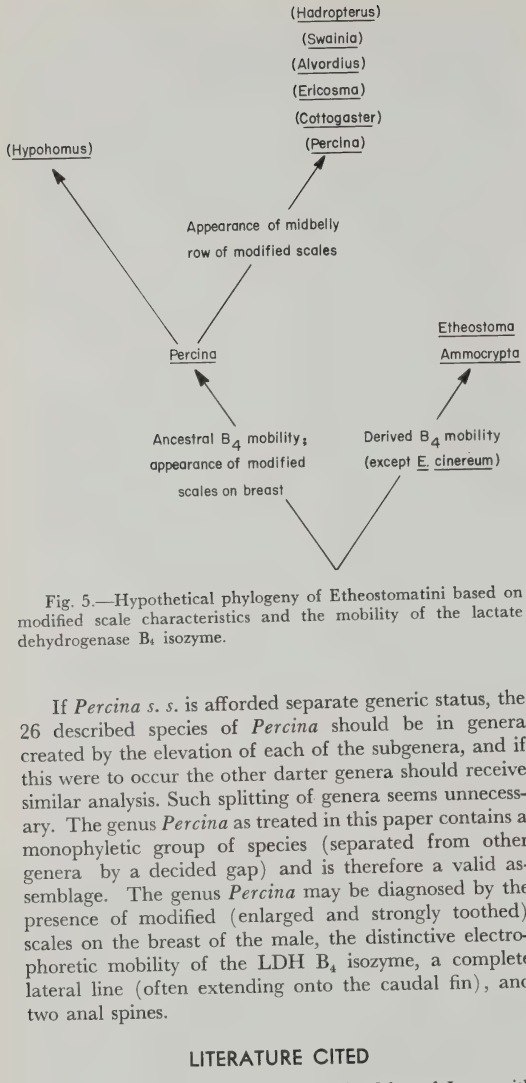

Fig. 5.—Hypothetical phylogeny of Etheostomatini based on modified scale characteristics and the mobility of the lactate dehydrogenase B_4 isozyme.

If *Percina s. s.* is afforded separate generic status, the 26 described species of *Percina* should be in genera created by the elevation of each of the subgenera, and if this were to occur the other darter genera should receive similar analysis. Such splitting of genera seems unnecessary. The genus *Percina* as treated in this paper contains a monophyletic group of species (separated from other genera by a decided gap) and is therefore a valid assemblage. The genus *Percina* may be diagnosed by the presence of modified (enlarged and strongly toothed) scales on the breast of the male, the distinctive electrophoretic mobility of the LDH B_4 isozyme, a complete lateral line (often extending onto the caudal fin), and two anal spines.

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ILLINOIS BIRDS: Laniidae

Biological Notes No. 83

RICHARD R. GRABER · JEAN W. GRABER · ETHELYN L. KIRK

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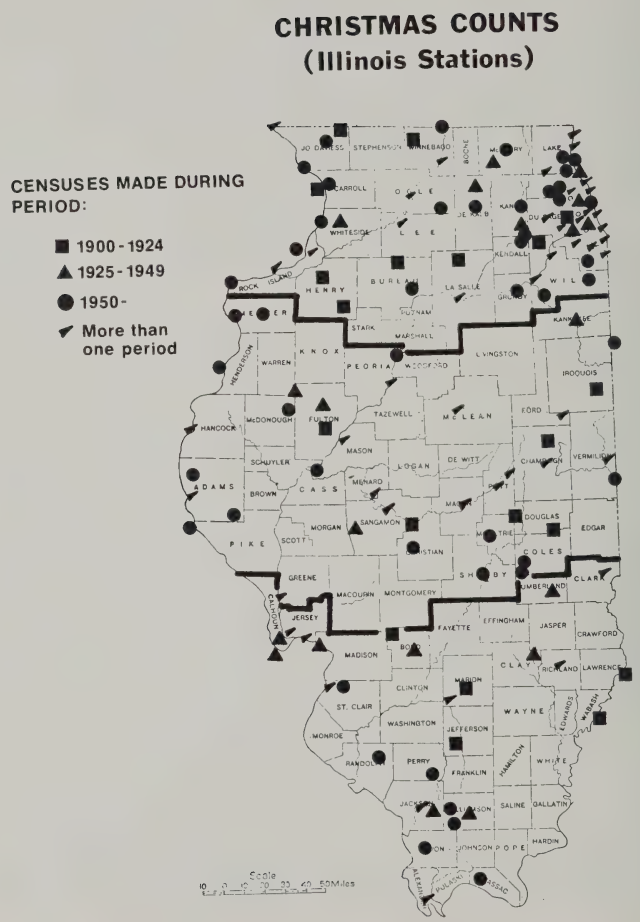


Fig. 1. — Localities in which Audubon Society Christmas counts have been made, and from which data have been used for our reports on Illinois birds. Localities which touch Illinois or its natural boundaries have been included.

LINOIS BIRDS: Laniidae

Richard R. Graber, Jean W. Graber, and Ethelyn L. Kirk

THIS PAPER ON THE SHRIKES of Illinois is the fourth in a series intended to summarize the ailable knowledge on birds of Illinois. The basic goals, ocedures, and policies of the project were outlined in introduction to the first paper (Graber et al. 1970). the introductions to subsequent papers we have con- ered in more detail various problems in the interpreta- n and presentation of data on Illinois birds.

Much of the information presented comes from the rature. Data from this source are so widely dispersed ough the thousands of papers published in the past tury that they are essentially lost to most students of ds. We estimate that our bibliography on Illinois birds nore than 85 percent complete. The literature avail- e to us is primarily that in the collective libraries of University of Illinois, including the Illinois Natural tory Survey Library, but we are also making use of erlibrary loans to fill in the gaps. The search for pub- ed reports continues, and we add worthwhile papers, h old and new, to the bibliography each year. For each ily account we try to have the literature coverage rent to the time our manuscript is submitted, i.e. usu- within a year of the date of publication. An inherent ger of a definitive project of this sort is that students be overly trusting of our coverage of the literature. urge all students who use the papers to weigh our mary of the literature against their own knowledge llinois birds and the pertinent literature. Corrections ny errors, whether of omission or commission, should er be published separately, or brought to our attention.

For a number of species of birds, including the shrikes, only semblance of winter population data available Illinois are those from the National Audubon Society's ual Christmas counts which were started in 1900. We e used data from all of the Illinois census stations and se which touch Illinois or its natural boundaries (Fig. including data published in the (Illinois) Audubon letin and Iowa Bird Life. We have tried various kinds nalyses on the Christmas count data, such as calcu- ons of frequency of occurrence by census, by year and decade, and calculations of numbers of birds per cen- per hour of observation, and per mile traveled.

The limitations in treatment of the Christmas count rmation are dictated by the rough and incomplete ure of the raw field data. In the case of shrikes, for mple, it can be shown that, on the average, more than hours of observation and 8,000 miles of travel have n required for a party of observers to see a northern ke in central Illinois in winter. When we consider that the sum of all central Illinois counts, beginning in 1902, did not comprise 600 hours of observation time until the count was in its fourth decade, until about 1935, we can see the serious limitations of the count for studies of long-term population changes, particularly for relatively uncommon species. No calculations, either of frequency of occurrence or population density, can have meaning based on such incomplete coverage.

Besides their poor coverage, the early counts were also short on important collateral data, such as mileage traveled, habitats covered, and weather information. Another drawback of the counts, pointed up particularly well by the shrike data, is the problem of inaccurate identifications. Our analysis (see under species account of the northern shrike) indicates that the two Illinois shrike species have sometimes been confused by students, though not necessarily more so on the Christmas counts than generally in winter.

In important ways the counts have improved in recent decades — more complete coverage, more complete station data, and better informed participants in the counts. Thus, in presenting data from the Christmas counts we tend to emphasize the information for more recent decades, especially since 1940. In general, we have accepted species identifications as given except for instances where the data differ markedly from our personal observations.

In our graphs on the occurrence of shrikes in the Christmas counts we have plotted data as the number of birds seen per 100 party hours of observation (a "party hour" can be defined as an hour of observation time by a group of observers, considered as a single observer). We used hours as the measure of censusing instead of miles traveled, despite the fact that mileage shows better correlation with numbers of shrikes seen ($r = .617$) than do the hour data ($r = .415$). We adopted this course only because some census takers still do not provide mileage data.

It is a pleasure to acknowledge James and Loraine Funk of Liberty, Thomas May of Lenzburg, and Michael Morrison of Sparta for providing valuable information used in this report. Our colleagues William L. Anderson, Ronald Labisky, and James Seets of the Survey made particularly important contributions in the form of field data and specimens. We are also especially indebted to Milton W. Sanderson, of the Survey's Faunistic Section, who patiently identified numerous fragments of insects from the stomachs of shrike specimens. John Unzicker and Wallace LaBerge identified spiders and Hymenoptera specimens for us, and James Appleby and George Godfrey identified the corn borer larvae. Staff members of the Survey's Wildlife Research Office and Editorial Office provided characteristically fine help in the preparation

his paper, in the biological notes series, is published in part with e funds. Dr. Richard R. Graber and Dr. Jean W. Graber are Wildlife alists in the Section of Wildlife Research of the Illinois Natural History y. The late Miss Ethelyn Kirk served as Technical Assistant in the on of Wildlife Research at the Survey.

and editing of the manuscript, and the preparation of figures and photographs.

LOGGERHEAD SHRIKE *(Lanius ludovicianus)*

(Fig. 2 and 3)

Spring Migration

Two interesting observations by Otto Widmann of St. Louis constitute the sum of knowledge on the diel timing of migration of the loggerhead shrike. He observed what was apparently diurnal migration — a solitary shrike flying north, out of sight, at 11:00 AM on March 14 (Cooke & Widmann 1884). Seemingly contrary, but not necessarily so, was Widmann's (1922) observation of strong *zugunruhe* (migration restlessness) in a captive shrike every night in October, starting about 9:00 PM. Was this behavior indicative of nocturnal migration?

Though loggerhead shrikes have been recorded in a

Fig. 2. — Loggerhead shrike at its nest (Pope County).

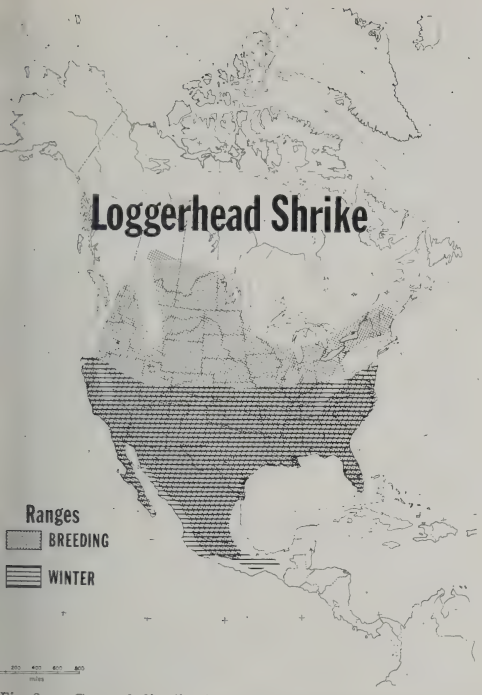


Fig. 3. — General distribution of the loggerhead shrike.

ions of the state in all seasons of the year, there is a ectable spring influx of shrikes, even in southern Illi-s, which has a notable winter population (Fig. 4).

Cooke (1888) believed the shrike migration began as ly as January 31 in the St. Louis area, though the k did not arrive until March 22. Our counts of shrikes southern Illinois show a marked increase after Feb-ry 20, and a peak in late March (Fig. 4).

Shrikes were extirpated in central and northern Illi-s before our censuses of the migration were made, but er references indicate a spring migration season similar hat in the south. In central Illinois the earliest arrivals e been noted in mid- and late February (DuMont 7, Musselman 1934–1935, 1938), with more pro-nced influxes throughout March, and largest numbers r March 20 (Ekblaw & Ekblaw 1916, Ekblaw 1917, th 1917). In the north, February records are excep-al, and there is almost no indication of the migration il March (Bartel & Reuss 1932, Gault 1901). Ford l. (1934) calculated the average arrival date of the gerhead shrike to the Chicago area to be March 18, Ferry (1908) noted that the species became common March 23.

ribution

The general distribution of the loggerhead shrike is wn in Fig. 3. The Illinois distribution was never accurately known, and the absence of records in a number of counties (Fig. 5) may be more related to inadequate exploration than to an actual absence of shrikes. We are certain, however, based on extensive searches in the past few years, that most of the population in northern and central Illinois has disappeared since 1965. In this vast area there are probably only a few scattered pairs left. We found only one nest (Mercer County) between 1968 and 1972 after searching large areas of central and northern Illinois. What is left of the state population today is nearly all south of the latitude of Pike and Cumberland counties (Fig. 5).

Nesting Habitats and Populations

Robertson (1942) recorded a shrike nest in oak-hickory forest, but this is exceptional habitat for the species. Most of the nests in Illinois have been recorded in roadside hedges in open country. Ridgway (1887) said the shrike liked open areas with thorn trees, such as the honey locust and wild crabapple.

Most of the nests found in central and northern Illinois have been in osage orange. In the south, nest sites have been much more diversified, though red cedar, rose, and osage orange seemed most favored (Table 1). Ridgway (1887), referring to the south, and Gates (1911) in central Illinois both mentioned the shrike as an orchard bird.

There are also numerous references in the literature to the nesting of shrikes in hedges, but there has been no systematic study as to what truly constitutes shrike habitat, i.e., foraging as well as nesting habitat requirements. Scattered young osage orange trees along the margins of cultivated fields would seem to be loggerhead shrike habitat in its simplest form, but just what and how much of such a combination the shrike uses is unknown.

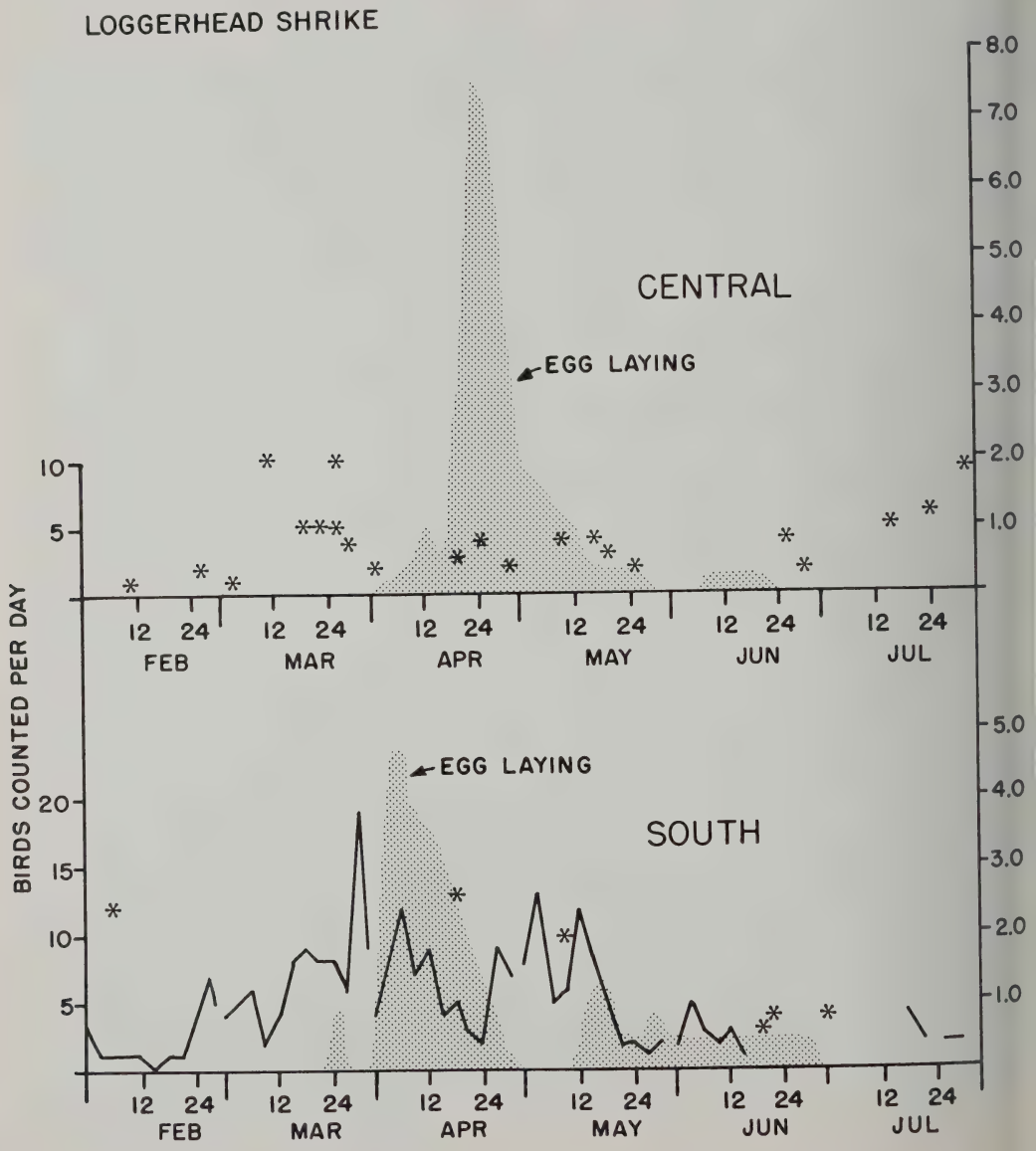
There have been no measurements of shrike territories in Illinois.

Reports that the shrike population in northern and central Illinois was declining began at least as early as 1910 (Hess 1910, Eifrig 1919, Work 1933, DuMont 1947 and 1947*a*, Mayfield 1949, Mumford 1960). The reason consistently postulated for the decline was the elimination of hedgerows (Hess 1910, Eifrig 1937, Blocher 1933, Nice 1945, Mayfield 1949). Osage hedges became a prominent feature of the Illinois landscape after 1840, partly due to the vigorous promotion of the plant as a living fence by Jonathan Baldwin Turner (Harkin 1962). With the advent of barbed wire about 1880, removal of the hedges began, and though there are still many fine osage hedges left in the state, they are rapidly being eliminated. There are no records to show what plants were used by nesting shrikes before osage became so prominent, but there are many observations which show that shrikes definitely adopted the new hedges for nesting (op. cit.).

The effect of the osage promotion on the shrike population cannot be assessed for lack of shrike population data. Kennicott (1853–1854) called the loggerhead shrike an abundant species in Illinois, but such a statement

cannot be interpreted numerically. Even in the 20th century when many observers felt that both the shrike population and the hedge population were declining, no one made meaningful measurements to show the change. The earliest reference that could be called even roughly quantitative was Eifrig's (1937) statement: "Formerly a pair [of shrikes] could be seen every two or three miles along the road, now one may drive for days without seeing one." This statement presumably referred to the Chicago area, where, a few years later, Bartel (1942) recorded two shrikes on a 100-mile road transect made May 26, 1942. Near Springfield, Illinois a much higher count of shrikes was obtained in 1946 (date not given): 35 adult shrikes along a 24-mile stretch of highway (DuMont & Smith 1946).

Despite numerous subjective references to a declining



rike population in Illinois, no firm data were collected ntil the 1950's. In 1957 Ronald F. Labisky of the Illinois atural History Survey made a record of the number of esting pairs of shrikes on the roadsides of a 36-square-ile area of agricultural land near Sibley, Illinois (Ford d McLean counties). In succeeding years we continued e survey and witnessed a steady decline of the shrike pulation until none were left in the area by 1966 (Fig. . Our extensive searches elsewhere between 1966 and 72 revealed that what had happened to the shrike pop-ation in the Sibley area also happened over most of rthern and central Illinois. Furthermore, the shrike pulation has declined in much of the Midwest (May-ld 1949, Petersen 1965, Erdman 1970).

Was this near extirpation related to the decline of dgerows? In 1958 we measured the roadside hedgerows the 36-square-mile Sibley study area, and found 5.2 lin-r miles of hedge. With 10 pairs nesting in the area that ar (Fig. 6), the density was 1.9 nests per mile of hedge. 1959 the hedge declined to 4.8 linear miles, and the mber of nests to 8, or 1.7 per mile of hedge. We did measure the hedges of the study area again until 72, when there were still 3.7 miles of roadside hedge no nesting shrikes. There were, in addition, at least miles of hedges in the area which were not along ds. In view of the quantity of hedge still left in the a, the disappearance of the shrikes would seem to uire some other explanation than just the reduction hedges. Another change which occurred in the Sibley a during the period when shrikes disappeared was a rked reduction in the acreage of hayfields (William Edwards and G. Blair Joselyn, personal communica-ns). We have no data from which to evaluate the ct of this change on the shrike, but it may have been portant, depending upon the value of hayfields as aging habitat for shrikes.

In summary, there apparently were two levels of nge in the shrike population of northern and central Illinois — a relatively slow decline since about 1900, probably related to the removal of hedges in many areas,

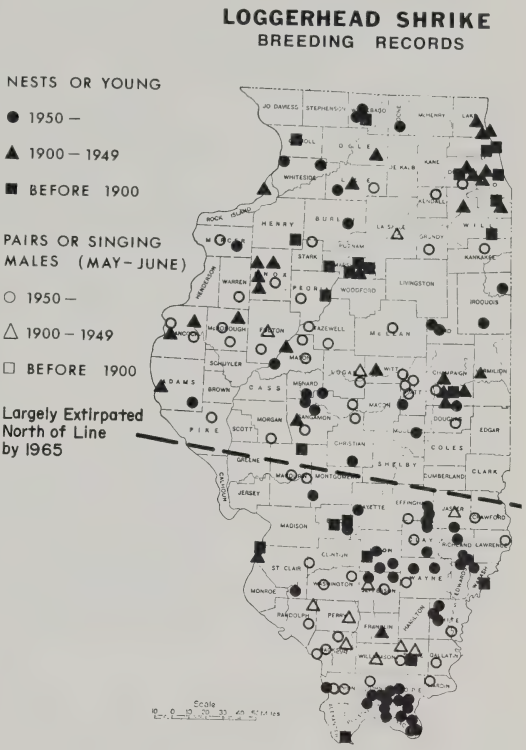


Fig. 5. — Breeding records for the loggerhead shrike in Illinois. Singing male records are for May and June only.

Fig. 4. — (To left and below.) Egg laying and migration seasons of the loggerhead shrike in Illinois. Spring and fall graph lines w the highest daily count of each 3 days (left scale) in southern Illinois, 1967 and 1970. Asterisks represent counts made either ther years or by other observers. Shaded areas show the percent of eggs laid on a given date (right scale).

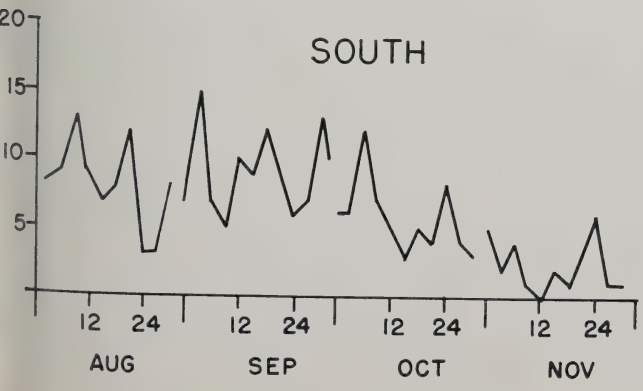


TABLE 1. — Plants used by loggerhead shrikes as nest sites in Illinois.

Species	Percent of Total Nests	
	North and Central (89 Nests)	South (55 Nests)
Osage orange *(Maclura pomifera)*	88	11
Red cedar *(Juniperus virginiana)*	..	20
Rose *(Rosa multiflora* and sp.)	..	13
Sassafras *(Sassafras albidum)*	..	9
Japanese honeysuckle *(Lonicera japonica)*	..	9
Hawthorn *(Crataegus* sp.)	3	5
Apple and crabapple *(Malus* sp.)	..	7
Cherry and plum *(Prunus serotina* and sp.)	2	4
Grape *(Vitis* sp.)	6	..
Elm *(Ulmus* sp.)	..	5
Pear *(Pyrus communis)*	..	4
Honey locust *(Gleditsia triacanthos)*	..	4
Oak *(Quercus* sp.)	..	2
Greenbrier *(Smilax* sp.)	..	2
Virginia creeper *(Parthenocissus quinquefolia)*	..	2
Pine *(Pinus* sp.)	..	2
Box-elder *(Acer negundo)*	..	2
Poplar *(Populus* sp.)	1	

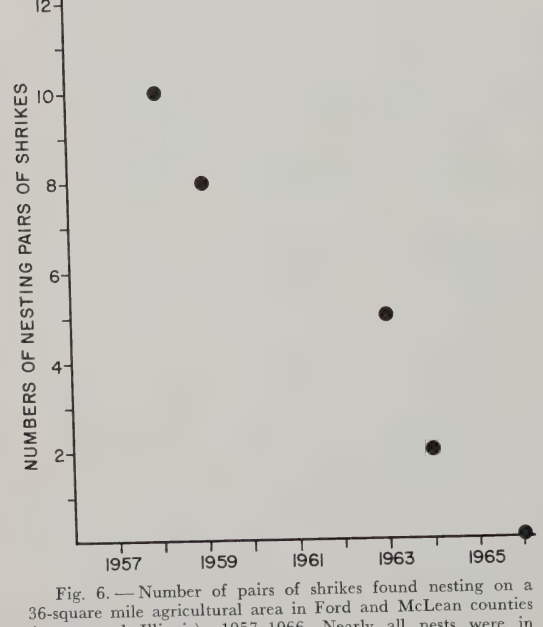


Fig. 6. — Number of pairs of shrikes found nesting on a 36-square mile agricultural area in Ford and McLean counties (east-central Illinois), 1957–1966. Nearly all nests were in osage orange hedges.

and a very rapid decline to near zero between 1957 and 1965 from causes unknown. It is possible, of course, that this change is temporary, but as of 1972 we have seen no sign of recovery by the shrike population.

Nesting Cycle

The song and call notes of the loggerhead shrike are highly varied and interesting, with both sweet notes and (more often) harsh, guttural notes, both somewhat resembling those of the mockingbird (Ridgway 1889). The shrike is not a persistent songster and its vocalizations are not as well known as those of other common species. We have seldom heard the song and have no data on the seasonal periodicity of singing in this species.

Among Illinois songbirds, the loggerhead shrike is an early nester, but Strode's (1918) statement that nesting (in central Illinois) may begin in early March is not literally true. Musselman (1937) observed completely built shrike nests on March 20, 1936 in central Illinois and even this is probably early for the region. Cook (1888) believed that shrikes began mating in the St. Louis area the day after they arrived (March 22) from the wintering grounds. During Gault's (unpublished notes) many years of observation in northeastern Illinois the earliest date on which he recorded a completed nest was April 8, while April 16–21 were more typical dates for this stage in the nesting cycle.

The earliest laying dates recorded are March 24 for southern Illinois, April 3 for the central region, and April 15 for the north. The peak in egg production comes in early April in southern Illinois, and in the latter half of April in central Illinois (Fig. 4). There are no comparable data for northern Illinois.

The nests are superficially like thrasher nests, being coarse, bulky structures made of sticks, weed stems, and grass. However, shrike nests are almost always very warmly lined with feathers or fur, or both (Fig. 5). Nehrling 1881, Blocher 1933). There are few records to indicate the time requirement for nest construction by loggerhead shrikes. Gault (unpublished notes, 1960) observed a nest under construction and/or waiting for eggs 11 days in northern Illinois, and in southern Illinois we have recorded nest-building periods of at least 5 days and 7 days, both nests having been partly completed when found. Five nests in central and southern Illinois had incubation periods of 17 days, and the nestling life of two nests in southern Illinois was 16 and 17 days. Thus the time requirement for one nesting cycle for a nest with six eggs is about 45 days.

Eaton's (1878) statement that the loggerhead shrike rears two broods (northern Illinois) is not borne out by our egg-laying data, at least for the population as a whole. Double-broodedness, if it occurs, is the exception rather than the rule in Illinois.

Most shrike nests in Illinois receive clutches of five eggs, though clutches of seven eggs and five eggs are uncommon (Table 2, Strode 1918, Hess 1910). In Ford County Blocher (1933*a*) found the usual clutch to be

Fig. 7. — Loggerhead shrike nest with eggs in osage orange near Bondville, Illinois, June 17, 1907. Photo by Alfred O. Gross.

s. The old oological records show a higher percentage five-egg clutches in the north than in central and thern Illinois, yet they indicated that even in the th the most frequent clutch size was six eggs. There no recent data for the north.

The loggerhead shrike has a notably high level of ing success for a songbird. A sample of 20 nests in dside hedges (red cedar, rose, sassafras, honeysuckle) outheastern Illinois in 1967 had a success rate (com- ed by the exposure day method, Mayfield 1961) of ercent (65 percent for eggs). By comparison, brown shers nesting in the same hedges had a success rate nly 42 percent of eggs (Graber et al. 1970). In east-

Table 2. — Clutch sizes of loggerhead shrikes in Illinois.

on	Number of Nests	Average Clutch	Percent of Nests by Clutch Size				
			7 Eggs	6 Eggs	5 Eggs	4 Eggs	3 Eggs
h[a]	37	5.9	24	41	35	0	0
ral	72	5.6	10	54	26	8	1
h	25	5.7	4	68	24	4	0

[a] The data for northern Illinois are mainly old museum records nd 1900 or before). The central and southern Illinois data are more , mainly since 1957.

central Illinois between 1958 and 1964, nesting success of shrikes in osage hedges was 71 percent (62 percent for eggs) in a sample of 25 nests. Thrashers in the same hedges had nesting success that varied annually from 34 to 38 percent of the eggs. Nests of thrashers and other species less fierce than shrikes perhaps aid shrike nests by absorbing most of the predation. The causes of failure of shrike nests are apparently unknown. We have never witnessed nest predation, and there is no reference on the subject in the Illinois literature. There are no data on the care of the young or duration of parental care. Young shrikes often remain in or near the nest tree for several days after fledging. Successful nests produced an average of 4.8 young per nest in central Illinois and 4.6 per nest in the south. Based on nesting successes of 71 percent and 80 percent, respectively, productivity at this stage is about 3 to 4 young per breeding pair, yet the fall populations are not particularly high (Fig. 4).

Fall Migration

The loggerhead shrike populations of northern and central Illinois had virtually disappeared 2 years before we started our censuses of the migration, and our seasonal

counts for those regions were negligible — not more than five birds seen per year.

Blocher (1933, 1933*a*) noted that shrikes were difficult to find after midsummer, and he put the fall departure before September. Others in northern Illinois made similar observations. In the period 1914–1917, inclusive, Schafer's (1917–1918) "last seen" dates for the loggerhead shrike varied from June 20 to August 16. In many years of observation in DuPage County, Benjamin Gault (1901*a* and unpublished notes) had very few late summer records for the shrike and his latest record for fall departure of the species was September 1. Ford et al. (1934) gives an average departure date from the Chicago area of September 18, and Oberholser (1918) gives October 3 for the average departure.

Late fall or winter departure dates may be misinterpreted on two accounts: (1) because loggerhead shrikes may occur in the north (rarely) even in winter, and (2) in late fall and winter there is a real possibility of misidentification of shrikes because incoming northern shrikes are very similar in appearance to loggerheads (Fig. 2 and 11). Late departure dates of October 12, November 1, November 11, and November 13 have been recorded for the loggerhead shrike in northern Illinois (Ford et al. 1934, Woodruff 1907, Oberholser 1918, Bent 1950), and November 9 has been recorded for the central region (Musselman 1930).

Apparently the fall migration of this species has never been witnessed, and we can only guess as to when the southward flights begin. In southern Illinois our counts showed a marked increase about the first of August and remained relatively high into October (Fig. 4). Whether the fall counts should be interpreted as productivity or increased conspicuousness of the shrikes for various reasons or as an indication of migration can not be resolved without banding or telemetry studies. The ratio of our spring-to-fall counts (1.0 shrike in spring to 1.5 in fall) is not indicative of the high nesting productivity observed in spring and summer (see under Nesting Cycle). The end of the fall migration is not clearly discernible in southern Illinois because shrikes winter there in good numbers. The counts do fall off abruptly in early October (Fig. 4), and this decline may represent the approximate end of the major fall migration.

Winter Records

Though the loggerhead shrike is a regular winter bird in southern Illinois, and there are some winter records for the species in central and northern Illinois (Fig. 8), there are no published banding data to show whether the winter population is made up of a nonmigratory remnant of the breeding population, late transients or winter immigrants from another breeding population, or some combination of these. The absence of winter records of the loggerhead from large areas of the state (Fig. 8) reflects both the paucity of observers, especially in the southern third of Illinois, where shrikes are relatively com-

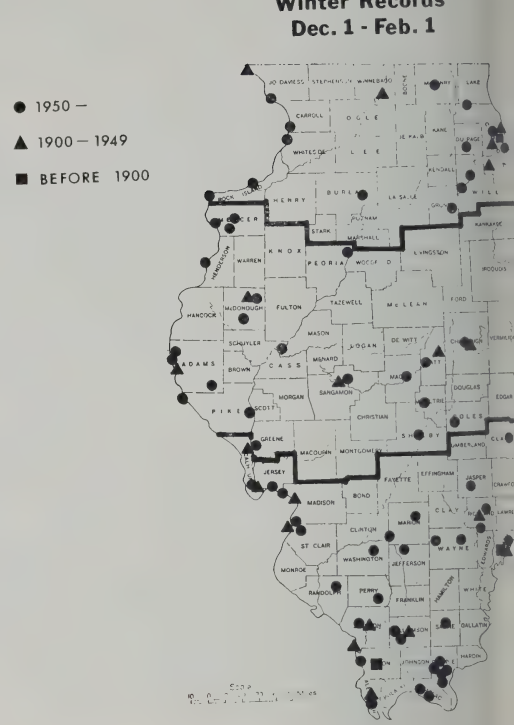


Fig. 8. — Winter records for the loggerhead shrike in Illinois. The three regions of the state discussed in the text are shown by the heavy lines.

mon, and an actual paucity of shrikes in the northern half of the state.

In northern and central Illinois the winter picture of shrike populations is complicated by the erratic occurrence of the northern shrike. Though the two species are distinct biologically, they are, as pointed out in the Fall Migration section above, so similar in appearance that they have been widely confused by bird students from earliest times. The erroneous belief held by some students that winter shrikes were likely to be the northern species has contributed to a number of errors in the Illinois literature, including the Christmas counts, but there is no certain way to separate false records from true. We have, therefore, arbitrarily based our acceptance of identifications on our own (not infallible) observations.

In summarizing the Christmas count data (Fig. 9) we have generally accepted identifications of loggerhead shrikes throughout the state. In the 73-year history of the Christmas count in Illinois, parties of observers have, on the average, required about 8 party hours to find a loggerhead shrike in southern Illinois, 60 hours in central Illinois, and 558 hours in the north. In recent decades

1951–1971) when mileage data were also provided, observers saw one loggerhead per 40 party miles traveled in southern Illinois, one per 260 miles in central Illinois, and one per 3,000 miles in the northern region (for regions see Fig. 8). The marked fluctuations in winter populations of the loggerhead shrike (Fig. 9) remain to be explained. Musselman (1939) suggested that more shrikes remained in Adams County in "mild years," but we know of no objective studies on the relationship of shrike populations to climate. The sharp decline of the northern and central Illinois breeding population of shrikes is not observable in the winter population figures, and this observation implies that the winter population may be different from the breeding population. We have noted that extreme west-central Illinois seems to have higher winter populations of loggerheads than other areas of central Illinois, but better census data are needed to confirm this.

Food Habits

The impaling of prey items in thorn trees, or on barbed wire fences is a well-known habit of shrikes. We once observed a shrike impaling dead birds, small migrants killed in September at a TV tower, on a nearby barbed wire fence. The use and function of the food cache is not fully known or understood (Ridgway 1889).

Depending on the source of information, we obtain two quite different pictures of the shrike's food habits in Illinois.

Direct field observations of foraging shrikes and of shrike food caches in all regions of the state have indicated that the loggerhead shrike is primarily predaceous

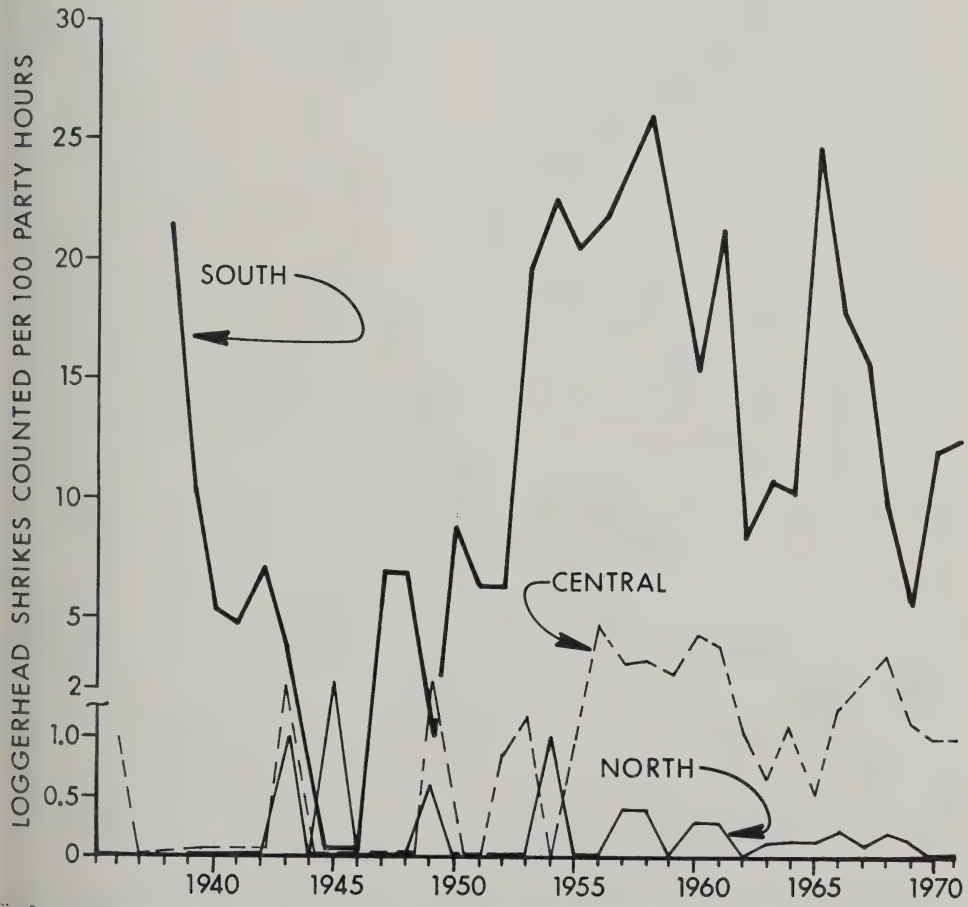


Fig. 9. — Annual variation in winter populations of the loggerhead shrike, based on Audubon Christmas counts in three regions the state. Graph lines show the number of loggerheads seen per 100 party hours.

on vertebrates, with small mammals (probably mainly *Microtus* and *Peromyscus*) predominating (Nearing 1961, Smith 1921, Breemfield 1921, Strode 1918). Songbirds have also been considered important prey. House sparrows (*Passer domesticus*) have been most often mentioned, but also juncos (*Junco hyemalis*), vesper sparrow (*Pooecetes gramineus*), Henslow's sparrow (*Passerherbulus henslowii*), field sparrow (*Spizella pusilla*), bluebird (*Sialia sialis*), horned lark (*Eremophila alpestris*), and downy woodpecker (*Dendrocopos pubescens*) (Farwell 1919, Miller 1935, Strumberg 1883, Vandercook 1921, Schafer 1921, and Woodruff 1897). Snakes, particularly garter snakes (*Thamnophis sirtalis*), and small frogs are frequently found in the food caches (Nearing 1961, Woodruff 1897), and the most commonly mentioned invertebrate in the caches are short-horned grasshoppers (Vandercook 1921, Vestal 1913, Ridgway 1889). We have seen a number of summer food caches in southern Illinois which consisted of only one or two items, always including either a vole (*Microtus*) or a house sparrow or both. One cache which we found on a barbed wire fence in late April in Johnson County, however, contained a bird skull (*Passer*?), three small frogs (*Acris crepitans*), a small garter snake (*Thamnophis*), two beetles (*Scarabaeidae*), and a moth, plus four regurgitated pellets, one of which we saw a shrike pin on the fence along with the other items.

Examination of the stomachs of a number of shrikes (62 adults and 9 stub-tailed juveniles) collected in southern Illinois indicates food habits different from the above (Table 3). The stomachs did contain numbers of grasshoppers (*Acrididae*), as expected from the field observations, but more dominant food items were ground beetles (*Carabidae*) and caterpillars, with vertebrates being much less frequent (Table 3). Many of the ground beetles were small, which suggests that shrikes forage a lot on the ground. Many of the caterpillars were European corn borers (*Ostrinia nubilalis*) which overwinter in cornstalks. How the shrikes get these insects is not known. There was no marked difference in adult and juvenile stomach contents. Though there are some interesting seasonal variations, e.g. the increased consumption of grasshoppers and Hymenoptera in late summer and fall, the consistent quality of the diet is even more impressive than the variations. Is the loggerhead shrike more dependent upon beetles and caterpillars than upon vertebrate prey for sustenance? From the present data we cannot say, and more systematic studies are required.

The food data do indicate the versatility of shrikes in foraging. Cleland (1922) and Breemfield (1921) observed shrikes catching prey by following farmers discing their fields. In describing predation by shrikes on house sparrows, Larsen (1897) observed that the shrike relentlessly chased a sparrow until it tired. In catching grasshoppers

TABLE 3. — Stomach contents of loggerhead shrikes collected in southern Illinois, 1971–1972.

Food Item	January		April		July		September-October	
	Percent of all Items	Percent Frequency of Occurrence (10 spec.)	Percent of all Items	Percent Frequency of Occurrence (31 spec.)	Percent of all Items	Percent Frequency of Occurrence (20 spec.)	Percent of all Items	Percent Frequency of Occurrence (10 spec.)
Diplopoda	1.1	10	1.0	6	0.9	5	..	.
Insects								
(Unspecified)	2.2	10	..	..	..	..	..	..
Orthoptera (grasshoppers)	11.2	40	5.2	19	29.3	65	29.4	60
Hemiptera (stink bugs)	1.1	10	0.5	3	0.9	5	..	..
Coleoptera (unspecified)	6.7	20	3.1	13	2.6	5	..	..
Carabidae (ground beetles)	18.0	60	51.1	84	25.0	65	14.7	40
Silphidae (carrion beetles)	..	..	..	..	2.6	5	..	..
Elateridae (wire worms)	..	..	0.5	3	..	..	..	..
Scarabaeidae (*Anomala*, dung beetles)	..	..	5.7	13	3.4	15	..	..
Cerambycidae (*Megacyllene*)	..	..	2.6	13	2.6	10	8.8	30
Curculionidae (snout beetles)	2.2	20	..	..	..	..	..	..
Lepidoptera (caterpillars only)	46.1	70	22.3	45	9.5	40	29.4	70
Hymenoptera (winged ants, wasps)	..	..	1.0	3	21.5	15	11.8	30
Arachnida (wolf spiders)	6.7	30	2.1	10	1.7	10	..	..
Vertebrates								
Small birds	1.1	10	0.5	3	..	..	..	..
Small mammals (*Microtus*, *Peromyscus*)	3.4	30	4.2	26	..	..	5.9	20
Plant material (twigs, grass)	..	10	..	..	..	5	..	..
Grit	..	..	..	..	..	5	..	..
Totals	*99.8*		*99.8*		*100.0*		*100.0*	

nd presumably other insects and mice, the shrike often overs a few feet above ground, then drops on its prey Vandercook 1921). Shrikes also drop on prey from an evated perch.

pecimen Data

There are many references in the Illinois literature the occurrence of "white-rumped" shrikes in the state Larsen 1897, Ridgway 1878, Loucks 1891, Gault 1899, ocher 1934). The identification of the Illinois breeding opulation was clarified by Ridgway (1889), and more lly by Miller (1931) who observed that though some inois specimens showed intergradation toward the estern race *excubitorides,* the Illinois population is operly allocated to *Lanius ludovicianus migrans.* An excellent series of 75 specimens, including many known nesting birds in the Survey collection, helps to verify the identification. Males appear more variable in color than females and about 20 percent of the males show some characters of the western form, but none are truly representative of *excubitorides.*

We have examined only 14 winter specimens, all *migrans.* The possibility of a winter influx of western shrikes exists, particularly to the western edge of the state, but identification of the western population depends on the collection of specimens. There are no consistent size differences between the sexes (Table 4). Winter specimens (in the hand, at least) can be sexed consistently on the basis of the gray vermiculations on the breast of females, males being much more nearly immaculate on the breast (Fig. 10). Wear reduces the difference

Table 4. — Weights and measurements of loggerhead shrikes collected in southern Illinois, 1971–1972.

e and Sex	Months	Number of Specimens	Gross Weight (grams)		Wing Chord (mm)		Tail Length (mm)	
			Range	Mean	Range	Mean	Range	Mean
ult male	Jan.	4	54.2–64.7	58.5	96.4– 99.4	97.8	92.0– 96.5	94.1
	April	17	47.9–57.9	53.0	92.7–101.8	98.7	88.6–101.4	95.5
	July	4	45.2–56.1	50.9	99.0–100.8	99.4	(badly worn)	
	Sept.-Oct.	8	51.9–57.3	54.4	(moulting)		(moulting)	
ult female	Jan.	7	46.8–57.0	53.5	93.8–102.2	97.8	90.1– 99.2	94.6
	April	16	50.9–74.3	61.1	93.3– 98.2	95.6	89.2– 99.5	93.1
	July	7	46.8–55.0	50.9	91.2– 97.0	94.2	91.2– 97.0	94.2

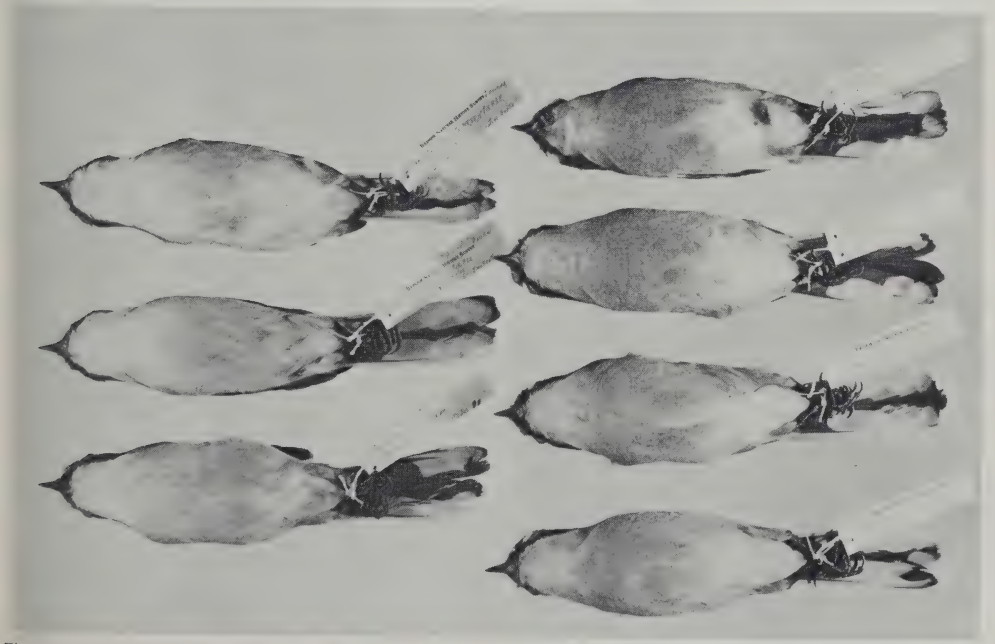


Fig. 10. — Sexual dimorphism in winter specimens of loggerhead shrikes. Females (right side) show more vermiculations on ast.

considerably by April. July specimens are badly worn and some, including adults, show the beginning of the molt. The molt appears to be prolonged, as all September and early October specimens are still in heavy molt.

NORTHERN SHRIKE *(Lanius excubitor)*

(Fig. 11 and 12)

The northern shrike is primarily a winter visitant to Illinois, and though there are numerous records for the species (Fig. 13) there are relatively few collected specimens. Because of the marked similarity between the northern shrike and the loggerhead (Fig. 2 and 11) sight records of the northern species in Illinois are a ways subject to question as, by the same token, a winter records of the loggerhead in the northern ha of the state. There is no way to determine the validi of most of the published winter records of shrikes northern Illinois, and discussion of the distribution (Fi 13) is problematical. The two species *are* identifiab with care, however, and we have generally accepte shrike records (as given) for northern Illinois as we as for central Illinois from observers with considerab field experience. On the other hand, we have found

Fig. 11. — Northern shrike. This species is slightly larger and paler gray than the loggerhead, with less black on the forehead yellowish, vs. black, mandible, and a stronger bill. Most Illinois specimens have very faint vermiculations on the breast, but so plumages and populations of the northern shrike are more heavily vermiculated than the specimen shown.

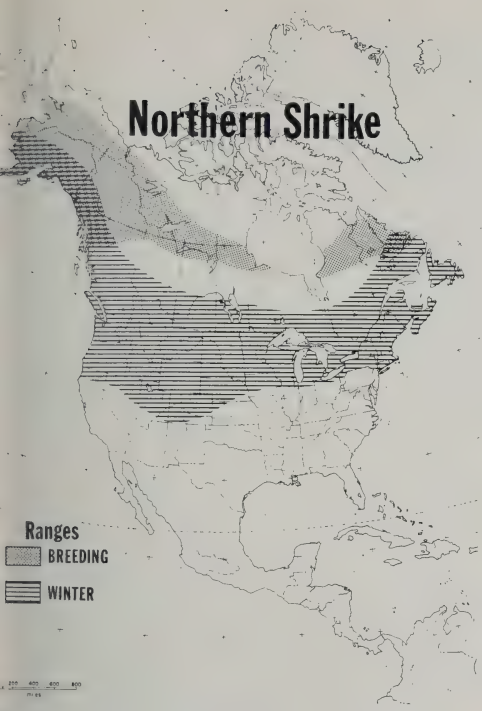


Fig. 12. — North American distribution of the northern ke. The species is also widely distributed in the Old World.

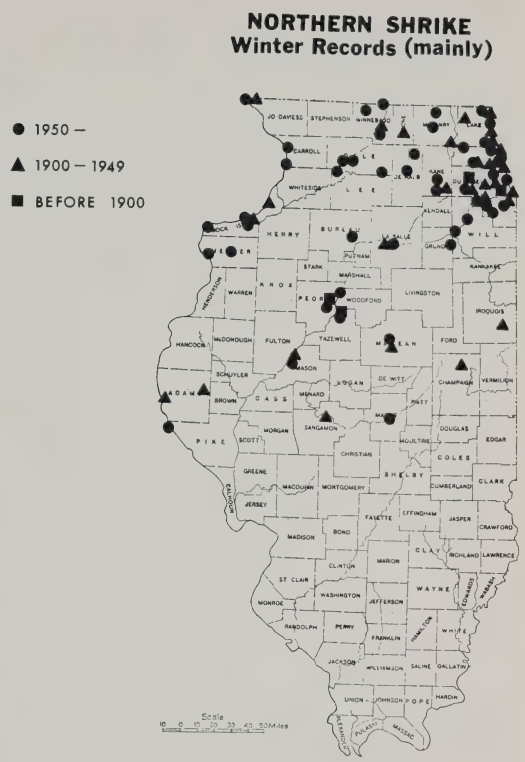


Fig. 13. — Northern shrike records for Illinois. A number of published records, especially for southern Illinois, were unacceptable, and not plotted. Most, but not all, of the records are for the cold months (November-February).

tain proof of the occurrence of the northern shrike the southern Illinois area, despite the number of published reports to the contrary (Hurter 1884, Widmann 07 and 1922, Comfort 1941, and Christmas counts for 0, 1949, 1950, 1955, 1958, 1960, 1962, 1965). Hurter 84) implies the existence of a specimen taken in the Louis area, but we have not located it. In the absence specimens, photographs, or other very carefully documented records, we have discounted all reports of the thern shrike for the southern half of Illinois (Fig. 13). The seasonal distribution of the northern shrike in nois is just as problematical as the geographic distribu-. Published records for the state run from October to April 16 (Ferry 1907, Bartel & Reuss 1932). We ted most of the northern shrike records for Illinois date (Fig. 14), and found that the records were fairly formly distributed from October 20 through March, ept for three definite peaks — in late October, late rch, and during the Christmas count period. The istmas peak probably mainly reflects the increased inst and coverage of observers preparing for and/or ducting censuses. The late October and March peaks cide suspiciously with the fall and spring migrations he loggerhead shrike in Illinois (Fig. 4 and 14). It f course, possible that these are periods of increased bers for the northern shrike as well, or periods of increased observer activity. Some observers state that there is a definite influx of northern shrikes in December (Nolan 1955, Petersen 1954), and the Christmas peak may thus be more than just increased observer activity, i.e., related directly to the biology of the northern shrike.

Though the Christmas count data are crude, they comprise the only semblance of population data for the northern shrike in Illinois (Fig. 15). Over the 73-year history of the Christmas count, observers in northern Illinois have seen northern shrikes at the rate of about one per 140 party hours of observation versus about 560 hours per loggerhead shrike. In central Illinois the rate was one northern shrike per 680 party hours, versus only 60 hours per loggerhead. For the more recent years (1951–1970) when relatively complete mileage data were provided for the counts, observers saw one northern shrike per 800 party miles traveled in northern Illinois, and one per 8,000 miles in the central region.

In recent decades northern shrikes have been reported every year in northern Illinois, but only about one year in three in the central region (Fig. 15). Even in northern Illinois the population shows marked annual

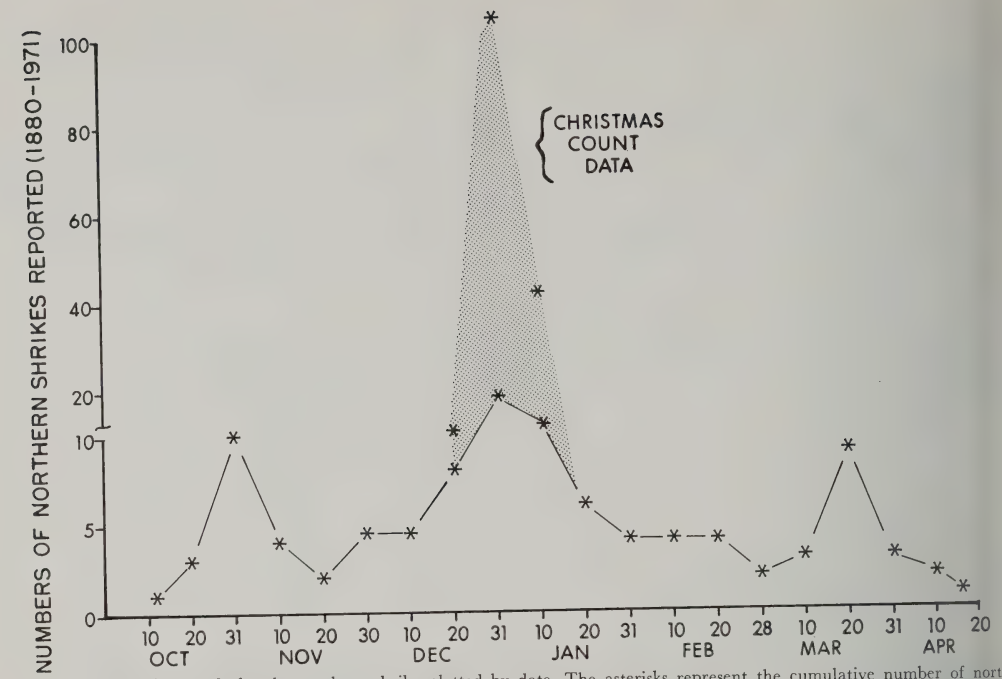


Fig. 14. — Illinois records for the northern shrike plotted by date. The asterisks represent the cumulative number of north shrikes seen for each 10-day (approximate) interval — October 1–10, 11–20, 21–31 — for the years 1880–1971 inclusive. The sha area represents data from the Christmas counts.

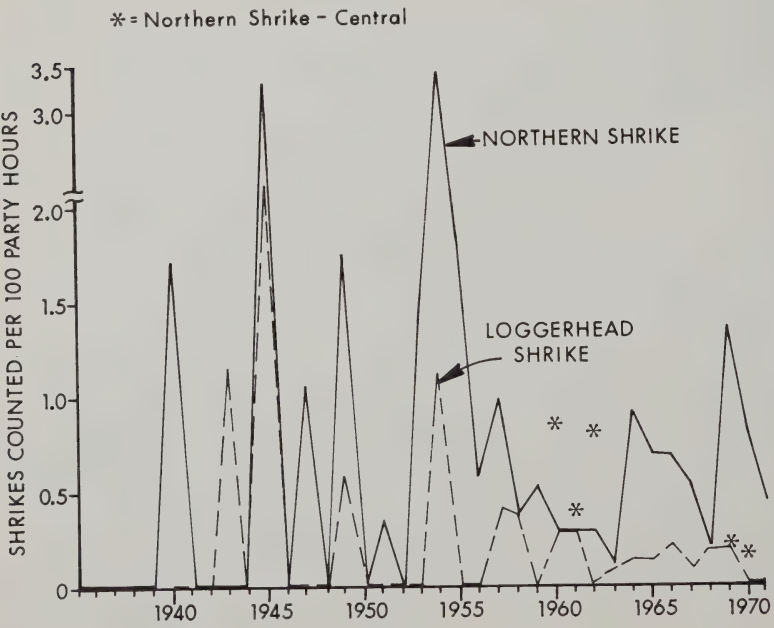


Fig. 15. — Annual variatio winter populations of the nort and loggerhead shrikes, based Audubon Christmas counts in nc ern and central Illinois. Graph show the number of northern loggerhead shrikes seen per party hours in northern Illi Asterisks show northern shrike ulations in central Illinois for y when the species was recor Zero counts, i.e. most years, not plotted for the central reg

riation, and we can see no consistent pattern to the riation (Fig. 15), i.e., peak invasions do not appear to predictable. Essentially nothing is known of the causes northern shrike immigrations, or of the biology of the ecies in Illinois.

All references to the food of the northern shrike in inois concern only one type of prey, several species of ds, most notably juncos and house sparrows (Sanborn 21, Ekblaw 1920, Mayfield 1950, Gault unpublished tes 1898). Burtis Wilson's notes (up to 1904) on the venport, Iowa area related that northern shrikes had quently come into the city to catch sparrows in earlier ars (pre-1900), but later were rarely seen (Hodges 54). Northern shrikes have occasionally proved an- ying to bird banders by entering their traps to kill ds (Sanborn 1921, 1922). Lyon (1930) often killed ikes for this reason. Like loggerheads, northern shrikes ve the habit of impaling their prey in thorn trees chafer 1921, Ferry 1907).

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TERACTIONS OF INTENSIVE CULTURES : CHANNEL CATFISH WITH LARGEMOUTH BASS ND BLUEGILLS IN 1-ACRE PONDS

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Interactions of Intensive Cultures of Channel Catfish With Largemouth Bass and Bluegills in 1-Acre Ponds

D. Homer Buck, Richard J. Baur, and C. Russell Ros

Development of techniques for the pond culture of channel catfish (*Ictalurus punctatus*), and increasing use of the species in both tropical and temperate climates, have stimulated interest in the feasibility of combining channel catfish production with other pond cultures. In an earlier study (Buck et al. 1972) we examined the compatibility of channel catfish and golden shiners (*Notemigonus crysoleucas*) in combined cultures. In the study reported here we have attempted to measure the nature of the interactions when intensive cultures of channel catfish were superimposed upon existing populations of largemouth bass (*Micropterus salmoides*) and bluegills (*Lepomis macrochirus*).

DESCRIPTION OF PONDS

The ponds used in these studies were originally constructed to be 100 feet (30.5 meters) wide and 436 feet (132.9 meters) long, and to provide a surface area of 1.0 acre (0.4 hectare) when maintained at maximum depths of 7 feet (2.13 meters). In the present study maximum pond depths fluctuated between 6 and 7 feet (1.8 and 2.1 meters), and average depths between 3 and 4 feet (0.9 and 1.2 meters). Because of shoreline erosion over the period since the date of pond construction (1963), it is believed that areas of 1.0 surface acre (0.4 hectare) were very closely approximated at the levels over which the depths fluctuated during the period of study. Water was supplied to the ponds by gravity from a 585-acre (236.7-hectare) reservoir. Drainage valves were contained in cement headwalls which supported short walkways out over the deepest parts of the ponds.

1970 EXPERIMENTS

Materials and Methods

In April and May, 1970, six 1-acre (0.4-hectare) study ponds were each stocked with 635 3- to 6-inch (7.6- to 15.2-centimeter) bluegills and 308 largemouth bass of mixed sizes and ages, including mature adults. We hoped that the initial stock could be sufficiently large to permit both species to attain carrying capacities by fall.

In May and June we superimposed channel catfis populations of two types (all caged; and half cage half free) upon four of the bass-bluegill population The other two ponds were maintained as contro having only bass and bluegills. Two additional pond were also maintained as controls with catfish onl half caged and half free. Thus, we had eight ponds – two with bass and bluegills only, two with catfish onl and two sets of two ponds each in which the catfis were combined with the bass and bluegills in tw different ways.

Each catfish population was composed of 1,60 5-inch individuals of which 850 were stocked on Ma 14 and 750 were stocked on June 11. In one of th two types of catfish populations 800 of the fish we released into the pond while the other 800 were co fined to cages; in the second type all 1,600 catfis were confined in two cages at rates of 800 per cage. A a convenience, each pond containing catfish was co sidered to have two population units, those stocke at a rate of 800 free in the pond, or those stocked rates of 800 per cage.

Cages used in this study were constructed by la ing ½-inch (1.27-centimeter) mesh hardware clo to a frame of thin-wall electric tubing of ½-inch (1.2 centimeter) diameter. Each cage was 4.5 feet (1. meters) long, 4 feet (1.22 meters) deep, and 4 fe (1.22 meters) wide, and was floated by Styrofoa to provide a water depth of about 3 feet (0.9 mete and a water volume of about 2 cubic yards (1.5 cub meters). Thus stocking was at a rate of 400 catfi per cubic yard (523 per cubic meter). Each ca was provided with a plywood cover having a "fee ing ring" in the center. The "ring" had rectangul dimensions of 11.25 x 22.5 inches (28.6 x 57.15 cen meters) enclosing a water surface of 1.76 square fe (0.16 square meter), and extending about 16 inch (40.6 centimeters) below the water surface. T ring was designed to control the rate of feeding a tivity and to prevent the feeding fish from splashi the floating food out of the cage. Cage design shown in the cover photo.

In earlier experiments (Buck et al. 1973) had fed both caged and uncaged catfish populatio a floating ration formulated as a supplemental fo for catfish free in ponds and found that this rat was inadequate for catfish that were confined cages, and resulted in high mortalities. In the pres experiments all feeding was with Purina trout cho

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COVER PHOTO: Illustration of catfish cage design with "feeding rings."

a more complete diet, which eliminated fighting and high mortalities. The catfish were fed twice daily for 5 days each week. Daily rations were 3 percent of body weight per day from the start of the first feeding period of June 15 until September 2, and were then increased to 3.5 percent until the time of census in October. Ration amounts were determined from the weighing of 300 catfish from each cage every 14 days; the uncaged catfish were not sampled. Actual computation of the ration was based on an average of all cage samples so that all populations received the same daily ration, both those in cages and those free in the pond. We now know that determination of the rations from cage samples only meant that the faster-growing uncaged fish were receiving less food per unit of body weight than were the caged catfish.

All populations were censused by pond drainage in October, 1970, at which time the bass and bluegills were returned to their ponds and the catfish were pooled in one pond and held overwinter for redistribution in the spring.

Results

Gross census data for 1970 (and 1971) are shown in Tables 1 and 2. Standing crops for both individual and combined species are shown in Table 3. Recoveries of all sizes of fish were believed to be generally quite complete, with the exception of the young-of-the-year bluegills stranded in the dewatered vegetation (mostly *Najas* spp.) which was quite abundant in most ponds in 1970. Although quite small in terms of total standing crops, the weights of the stranded fish were not estimated and the totals listed for bluegills in 1970 must be recognized as incomplete.

TABLE 1.—Fall standing crops after one and two growing seasons for largemouth bass (LMB) and bluegill (BG), when in the stocking combinations shown. Listed weights represent averages for two populations of each of the types indicated. (CC = channel catfish.)

Species Measured	Original Stock, Spring, 1970		Fall Standing Crops in Kilograms Per Hectare	
	Number	Kilograms	1970	1971
LMB (when in pond with BG)	308[a]	3.63	33.88	72.23
LMB (when in pond with BG and caged CC)	308	3.60	39.66	80.68
LMB (when in pond with BG, caged and free CC)	308	3.80	36.88	80.14
BG (when in pond with LMB)	635[b]	12.67	67.76[c]	232.56
BG (when in pond with LMB and caged CC)	635	13.11	79.11[c]	204.37
BG (when in pond with LMB, caged and free CC)	635	12.96	99.16[c]	301.95

[a] Bass populations all included 104 Age 1 fish stocked on 6/10/70, 4 adults stocked on 6/12/70, and 200 Age 0 stocked on 6/25/70.

[b] Total lengths of bluegills ranged from 7.6 to 15.2 centimeters; all were stocked within the period 4/7/70 to 5/12/70.

[c] Standing crops of bluegills for 1970 are incomplete because the stranding and loss in drainage of small but unknown weights of young-of-the-year in small sizes.

In the fall of 1970 the standing crops of bluegills older than Age 0 (original stock) were quite uniform from pond to pond, ranging from 257 to 338 in number, and from 50.20 to 76.63 pounds (22.77 to 34.76 kilograms) in weight. Survivals among populations of these older bluegills ranged from 40.5 to 53.2 percent. Age 0 bluegills were abundant in all ponds, but were mostly quite small and contributed relatively little to the total weights. In those ponds containing bass and bluegills, standing crops of channel catfish averaged 25 percent less in weight than the catfish in those ponds containing no bass and bluegills. These differences were due in part to predation on catfish by bass, and probably had no relation to the presence or absence of bluegills.

Age 0 bass contributed very little to the fall standing crops in 1970. No natural reproduction was observed, and the few surviving young-of-the-year originated from the 200 fry stocked in each pond on June 25, 1970. Survivors of this stock numbered 0 in three ponds, and 3, 5, and 22 in the remaining three ponds. Survivals among populations of older bass ranged from 31.5 to 75.0 percent, and weights ranged from 26.13 pounds (11.85 kilograms) to 41.58 pounds (18.86 kilograms).

As mentioned above, standing crops of channel catfish averaged less in the presence of bass and bluegills. It is probably significant that the poorest survival of channel catfish was associated with the largest survival of bass. In one pond, in which only 34 of the 108 older bass survived (31.5 percent), the survival among 800 channel catfish released into the pond was 658 (82.2 percent), a figure quite close to that for the caged population in the same pond (689); however, in its replicated pond the survival of 81 bass older than Age 0 was the highest of any pond (75.0 percent), and the survival among the 800 catfish released into the pond was only 371, by far the lowest of any population, caged or otherwise. It seems apparent that some predation of channel catfish by bass must have occurred in this first season when many of the catfish were still small enough to be eaten by the larger bass.

We may consider the catfish in four categories: those either caged or free in the ponds with bass and bluegills, and those caged or free in the ponds without bass and bluegills. Standing crops of catfish free in the ponds averaged heavier than those populations confined to cages, and catfish in ponds alone consistently outweighed those populations sharing the ponds with bass and bluegills (Table 3). However,

TABLE 2.—Fall standing crops after one and two growing seasons for channel catfish (CC), both caged and free i ponds, when in the stocking combinations shown. Listed weights represent averages for two populations of each of th types indicated, except as noted.

Species Measured	Standing Crops Per Unit of Catfish[a]				Standing Crops Per Hectare			
	1970		1971		1970		1971	
	Number	Kilograms	Number	Kilograms	Number	Kilograms	Number	Kilogram
CC caged (when in pond with free CC)	764	83.64	698	319.44	[e]	[e]	[e]	[e]
CC caged (when in pond with BG and LMB)	783[b]	71.36[b]	695[c]	274.96[c]	3,870	352.66	3,412[d]	1,423.67[d]
CC caged (when in pond with BG, LMB and free CC)	704	73.55	686	278.59	[e]	[e]	[e]	[e]
CC free (when in pond with caged CC)	794	100.54	676	357.53	[e]	[e]	[e]	[e]
CC free (when in pond with BG, LMB and caged CC)	515	76.30	654	361.50	[e]	[e]	[e]	[e]

[a] Catfish were Age 1, 12 grams in average weight, and numbered 800 per stocking unit (1,600 per pond) when stocked in 197 the same fish averaged 96 grams and numbered 700 per stocking unit, or 1,400 per pond, when stocked in 1971.

[b] Average of four, rather than two units of caged catfish. These averages are high because one of the four units was inadve tently stocked with 900, rather than 800 fish.

[c] Average of three, rather than two units of caged catfish.

[d] For one pond only due to loss of fish by asphyxiation.

[e] Could not be accurately computed because half of the catfish in any individual pond were caged and half were free.

TABLE 3.—Average standing crops in kilograms per hectare after one and two growing seasons for two populations of each of the combinations indicated.

	Channel Catfish		Bass	Bluegills[b]	All Species Combined
	Caged	Free			
1970	206.70	248.48			455.18
1971	789.45[a]	883.59[a]			1,673.04[a]
1970	181.71	188.56	36.88	99.16	506.31
1971	688.50	893.39	80.14	301.95	1,963.98
1970	352.91		39.66	79.11	471.68
1971	1,423.67[a]		80.68	204.37	1,708.72
1970			33.88	67.76	101.64
1971			72.23	232.56	304.79

[a] Data from one pond only.

[b] Standing crops of bluegills for 1970 are incomplete because of the stranding and loss in drainage of relatively small but unknown weights of young-of-the-year in small sizes.

in the later evaluation of data from both years we will see that the differences were probably not significant.

There was a surprising difference in production in the two ponds which contained catfish only. Caged populations had similar survivals (98 and 93 percent) and weights (181 and 187 pounds) (82.1 and 84.8 kilograms) in the two ponds, but the populations of unconfined fishes showed marked differences. In one pond the total weight of the free catfish was less than that of the caged fish, and this was associated with very clear water (average turbidity 10 ppm) and heavy weed growths (mostly *Najas* spp.). Observations made at the time of drainage disclosed a marked scarcity of damselflies and burrowing mayflies. In the replicate pond the standing crop of free catfish exceeded the weight of the caged population by almost 100 pounds (45.36 kilograms), or slightly over 50 percent, and this greater weight was associated with a higher average turbidity (35 ppm), an absenc of weeds, and an abundance of those natural food observed to be scarce in the other pond.

1971 EXPERIMENTS

Materials and Methods

Numbers and weights of bass and bluegills r stocked in October, 1970 to establish the 1971 popul tions are shown in Tables 4 and 5, along with standi crops recovered in the drainage censuses of Octob 1971.

The number of catfish available for stocking in t spring of 1971 was reduced below the 1970 level b intervening mortalities. The number recovered April 13 from the overwinter holding pond was suf cient to provide only 662 in each population unit, 1,324 in each of the six ponds. These were stock on April 13 and 14. In an effort to achieve a rando distribution of fishes of equal sizes, the fish to stocked were pooled in a large holding tank and we netted, weighed, and stocked in consecutive lots 50 to each unit until each had received nine lots tot ing 450 fish, then in lots of 40 until each had receiv an additional 120, and in progressively smaller l until each unit contained 662 fish. On May 19, 197 38 additional fish were stocked in each unit whi brought the totals to 700 per unit, or 1,400 catfi in each 1-acre (0.4-hectare) pond.

In 1971 in one pond, which happened to be co pletely weedless, it was possible to make a comple recovery of all of the bluegills including the small of the Age 0 fish. Numbers and weights of strand small fish were estimated in all other ponds. T estimates were based upon complete counts of sm fish stranded in randomly chosen sample areas. V

TABLE 4.—Numbers, ages, and total weights in kilograms of bluegills restocked following the 1970 fall census, with numbers, ages, and weights recovered in the fall census of 1971.

Pond Number	Stocked in October, 1970					Recovered in October, 1971				
	Age 0		Older			Age 0		Older		
	Number	Weight	Number	Weight	Total Weight	Number	Weight	Number	Weight	Total Weight
1	13,456	2.39	324	34.61	37.00	13,343	85.05	308	54.64	139.69
2	3,133	1.97	256	22.69	24.66	15,471	74.00	252	38.01	112.01
3	14,631	7.23	264	26.33	33.56	41,768	42.86	251	43.26	86.12
4	6,151	2.01	264	27.76	29.77	14,937	37.30	244	41.97	79.27
6	6,560	0.88	338	25.36	26.24	56,538	31.32	304	44.87	76.19
7	6,827	2.87	293	31.46	34.33	19,199	59.25	266	45.42	104.67

TABLE 5.—Numbers, ages, and total weights in kilograms of largemouth bass restocked following the 1970 fall census, with numbers, ages, and weights recovered in the fall census of 1971.

Pond Number	Stocked in October, 1970					Recovered in October, 1971				
	Age 0		Older			Age 0		Older		
	Number	Weight	Number	Weight	Total Weight	Number	Weight	Number	Weight	Total Weight
1	5	0.32	34	13.74	14.06	644	6.48	39	19.39	25.87
2	3	0.09	50	15.47	15.56	2,519	9.87	61	23.46	33.33
3	20	0.68	56	18.54	19.22	263	14.85	55	27.87	42.72
4	0		59	12.47	12.47	1,132	4.82	59	17.76	22.58
6	0		53	11.85	11.85	129	2.12	49	23.00	25.12
7	0		79	15.39	15.39	2,564	10.32	68	28.67	38.99

believe that the standing crops listed in 1971 are reliable and complete for all species.

With few exceptions, operating procedures in 1971 were much the same as in the previous year. The caged channel catfish populations were sampled only every 30 days in order to minimize loss of fish through handling in hot weather, and because it was not essential to our primary interest to achieve the most efficient feeding regime. Rations were increased on the basis of anticipated rates of conversion. An additional change in 1971 was that all cages were relined with nylon netting to prevent loss of fish through deterioration of the original wire netting.

Results

Standing crops of all three species were much larger in this second year (Tables 1 and 2), clearly establishing the hypothesis that carrying capacities had not been achieved in the first growing season.

For bluegills, substantial increases occurred in the weights of both Age 0 and older fish. Largest weights of both groups of bluegills occurred in the weedless pond where they were associated with caged and uncaged channel catfish. Table 6 shows that standing crops of bluegills in 1971 averaged highest in those ponds containing both caged and uncaged catfish, were intermediate when with bass only, and lowest when with bass and caged catfish; however, the differences were not significant at the .05 level. The only observable interaction between bluegills and catfish involved uncaged catfish and Age 0 bluegills. Table 6 shows that the lowest average number but the highest average weight of Age 0 bluegills occurred in those ponds where they were intermixed with uncaged catfish, suggesting that substantial numbers of young bluegills were eaten by the catfish. Table 6 also shows that only very minor differences occurred in either number or weights of older bluegills in the three types of populations. It appears evident that the association with catfish placed no serious limitations upon bluegill production, and that poundages may actually have been increased either through (1) thinning of the young, (2) utilization by the survivors of food intended for the catfish, or (3) enrichment of the environment through the addition of the catfish food.

Total weights of bass showed an average increase of more than 100 percent in 1971 over 1970, again emphasizing that carrying capacities had not been achieved in the previous growing season. Age 0 bass were present in all populations, and increases occurred in weights and numbers of both Age 0 and older fish. In 1971 the average difference in standing crops of bass sharing ponds with bluegills only, and of bass in ponds with bluegills and both caged and uncaged catfish was 7.06 pounds (3.20 kilograms), and in all

TABLE 6.—Fall standing crops by age groups in numbers and kilograms per hectare for largemouth bass (LMB) and bluegills (BG) after two growing seasons in the stocking combinations shown. Listed weights and numbers represent averages for two populations of each of the types indicated.

Species Measured	Age 0		Age 1 and Older		Total Weight
	Number	Weight	Number	Weight	
LMB (when in pond with BG)	3,272	14.83	136	57.40	72.23
LMB (when in pond with BG and caged CC)	1,725	24.30	141	56.38	80.68
LMB (when in pond with BG, caged and free CC)	3,963	20.76	133	59.38	80.14
BG (when in pond with LMB)	88,968	130.14	687	102.41	232.55
BG (when in pond with LMB and caged CC)	70,060	99.05	613	105.32	204.37
BG (when in pond with LMB, caged and free CC)	40,206	178.31	709	123.64	301.95

types of bass populations the difference was not significant at the .05 level. The results suggest that coexistence with a rather intensive culture of channel catfish had no measurable influence on the production of bass.

It was of further interest to observe that adults of both bass and bluegills were fatter in the presence of uncaged catfish than when separated from them. Bluegills intermixed with both bass and catfish had an average coefficient of condition (C) of 8.57; bluegills with bass only had an average condition of 7.41. For bass the averages were 5.07 when with both bluegills and catfish, and 4.74 when with bluegills only.

In 1971, mortalities averaged 1.0 percent in caged catfish populations and 5.4 percent in free populations. Among caged populations the difference between the highest and lowest rate of survival was only 12 fish (less than a 2-percent difference); among the uncaged populations the difference was only 26 fish, or less than a 4-percent difference. Average rates of survival of the two types of populations differed by less than 5 percent. Differences in weights, however, were considerably larger. Among the caged catfish the greatest weights were in those populations sharing the pond with uncaged catfish and in the absence of bass and bluegills. Among the uncaged catfish populations the greatest weights were made in those ponds containing bass and bluegills, but these were only slightly larger, and not significantly different from weights of those populations sharing the pond with caged catfish. Between caged and uncaged populations there was an average difference of 153.5 pounds (69.6 kilograms), or more than 19 percent. In terms of individual weights, uncaged catfish averaged about 0.29 pound (131.5 grams) heavier than those con fined to cages.

Standing crops of bluegills in the ponds were considerably larger than those in a sampling of othe unfertilized Illinois waters, and standing crops o bass were somewhat above average. At the end o two growing seasons our six populations of bluegill had standing crops ranging from 168 to 308 pound per acre (188.3 to 345.3 kilograms per hectare), wit an average of 219.7 (246.3) (Table 7). This compare with an average of 123.1 pounds per acre (13 kilograms per hectare) of bluegills obtained in seve censuses of bass-bluegill populations in 16-acre (6.5 hectare) Ridge Lake in central Illinois (Bennett et a 1969); with 104.9 pounds per acre (117.6 kilogram per hectare) of bluegill obtained in three censuse of mixed populations (predominantly bluegill) i 2.6-acre (1.05-hectare) Arrowhead Pond (Benne 1971), also in central Illinois; with 168 pounds pe acre (188.3 kilograms per hectare) obtained in thre ponds in southern Illinois (Hansen et al. 1960) whic averaged 0.83 acres (0.34 hectares) at the time census; and with 125.3 pounds per acre (140.5 kil grams per hectare) obtained by Buck & Thoits (197 in four single species populations in 1-acre (0. hectare) ponds in northern Illinois.

Our six bass populations averaged 69.3 pound per acre (77.7 kilograms per hectare), compare with 40.2 (45.1) in nine censuses of Ridge Lak 27.5 (30.8) in three censuses of Arrowhead Pon 70.0 (78.5) in Hansen's three ponds in southe Illinois; and 75.3 (84.4) in 11 single species popul tions in northern Illinois.

Our standing crops of channel catfish range from approximately 1,200 to 1,600 pounds per ac (1,345 to 1,794 kilograms per hectare), with average of about 1,370 (1,536). These fell somewh short of the range of 1,500 to 2,000 pounds per ac (1,682 to 2,242 kilograms per hectare) as predict by Lewis (1969), because numbers stocked in o ponds were reduced to 1,400 per acre (3,459 p hectare) in 1971, and the fish were fed only 5 da each week. For the production of food fish in Illino Lopinot & Fisher (1969) have suggested stocki 1,500 fish per acre (3,707 per hectare) and feedi 6 days each week.

As pointed out earlier, all units of populatio both caged and uncaged, received the same ratio but the amount of the ration was determined fr sampled weights of caged catfish only. Thus t faster-growing catfish free in the ponds were giv less food in terms of percentage of body weight th were the caged individuals. It is therefore interesti to observe that the uncaged individuals had not o a markedly greater average weight by 0.29 pou (131.5 grams), but a more efficient rate of conversi Among the caged fishes, conversion rates for in vidual populations ranged from 1.41 to 1.77, with average of 1.56; for the fish free in the pond

TABLE 7.—Comparison of standing crops of bluegills and largemouth bass in kilograms per hectare after two growing seasons in our ponds with standing crops measured in a cross section of other unfertilized Illinois waters.

Location	Average Size (Hectares)	Source	Bluegill		Largemouth Bass	
			Number of Ponds or Years	Average Per Hectare (Kilograms)	Number of Ponds or Years	Average Per Hectare (Kilograms)
Our ponds	0.4		6	246.3	6	77.7
Dundee ponds	0.4	Buck & Thoits (1970)	4	140.5	11	84.4
Hansen's ponds	0.34	Hansen et al. (1960)	3	188.3	3	78.5
Arrowhead Pond	1.05	*In* Bennett (1971)	3[a]	117.6	3	30.8
Ridge Lake	6.48	Bennett et al. (1969)	7	138.0	9	45.1

[a] Computed from years 1950, 1952, and 1953.

ange was from only 1.16 to 1.27, with an average of 1.24. Thus it is clear that the uncaged fish made efficient use of the pond's natural foods, and made significantly greater gains than the caged fish while receiving proportionately smaller rations. For example, when the final census weights were used to compute the percentages of total weight contained in the daily ration, the caged fish were receiving .31 percent of their weight, while the heavier and faster-growing uncaged fish were receiving a daily ration equivalent to only 1.03 percent of their weight.

DISCUSSION

It is widely accepted that the elimination of preexisting pond fishes is a prerequisite to the successful production of channel catfish in commercial quantities. It is believed that the companion fishes will utilize food intended for the catfish, and might further reduce the potential for catfish production through competition for oxygen and space. While this might very well be true for certain types of companion fishes, such as bullheads (*Ameiurus* sp.), or one of the carps (*Cyprinus* sp.), it may not be true for others. An earlier study (Buck et al. 1972) produced evidence that commercial quantities of both channel catfish and golden shiners can be raised in combined culture, and results of the present study suggest that channel catfish can be raised in commercial quantities in ponds containing established populations of bass and bluegills without detriment to either culture. Such a combination could retain the recreational aspects of a pond through angling provided by the bass and bluegills, while the catfish could provide additional angling pleasure and food for the table as well as a cash crop.

It should be recognized, however, that the combining of such species presents certain problems, and would require certain precautions. A primary precaution would be to avoid overstocking and overfeeding to the point that accumulated organic wastes could cause a depletion of the supply of oxygen.

A second precaution would be the stocking of feeder catfish of sufficient size to prevent excessive predation by the larger bass. In 1970 we suspected that poor survival of catfish in one pond may have been due to such predation. In this instance the catfish had an average total length of 5 inches (127 millimeters) when stocked, and the bass population contained eight individuals sufficiently large to prey upon catfish of this size; however, survival of catfish was almost twice as high in the replicate pond where the potential for predation was similar. When restocked in 1971, the catfish had an average total length of between 9 and 9.5 inches (228.6 and 241.3 millimeters), and predation was not a problem, although the bass were larger. The use of cages would, of course, permit use of smaller catfish and totally eliminate the predation problem. An additional precaution against predation would be to remove the larger bass at harvest time, along with excessive numbers of bluegills. Selected bass and bluegills might then be returned to the pond to preserve the angling population. While the sorting out of the bass and bluegills during the catfish harvest would constitute a considerable nuisance, it might be worth the effort. Additional cash income could well be realized through the sale of excessive bluegills and the larger bass since a ready market now exists for both species, in Illinois as well as elsewhere.

Harvesting of catfish could be simplified by confining them to cages, but our study showed greater gains on a lesser amount of feed by catfish when they were free in the pond to supplement their ration with natural foods. Elimination of cages would also obviate the labor and cost of their construction, and lessen food costs. As shown in a companion study (Buck et al. 1973), caged catfish require a more complete and much more expensive feed because they have only a very limited access to natural foods.

Further mention should also be made of the apparent interaction between the uncaged catfish and bluegills in 1971 wherein the smallest numbers but the greatest weights of Age 0 bluegills were found in those ponds containing uncaged catfish. The data suggested that the catfish production was improved through predation of the small bluegills, and that the population of bluegills was in turn improved through a beneficial thinning of their numbers by

the catfish. At the same time the presence of catfish had no apparent influence on the bass population.

Utilization of catfish food by bass and bluegills was not a problem in our trials. Bass were never observed to take pellets, and only a few of the larger bluegills were observed to converge around the cages, or to intermingle with the free catfish at feeding time. On the other hand, consumption of pellets by bluegills would be advantageous if it produced a larger, more marketable size of bluegill, as it well should.

In conclusion, it appears that combining of the species would have at least as many potential advantages as disadvantages, and could be of particular interest to a pond owner wishing to retain the recreational aspects of his pond while at the same time utilizing it as a source of income.

SUMMARY OF FINDINGS

1. The bass and bluegills in our experimental ponds failed to achieve carrying capacity in the first growing season; the standing crops after two seasons more than doubled the weight of those recovered after the first season.
2. After two growing seasons the standing crops of bluegills were heaviest in those ponds containing both caged and uncaged catfish, were intermediate when the bluegills were combined with bass only, and least when they were combined with bass and caged catfish.
3. The lowest number, but greatest weight, of Age 0 bluegills occurred when the bluegills were intermixed with uncaged catfish, suggesting that the catfish may have effected a beneficial thinning of the small bluegills.
4. Association with catfish placed no obvious limitations upon bluegill growth, and may have increased production through thinning of the young.
5. Spawning by both bass and bluegills appeared to be normal, and Age 0 fish of both species were abundant in the final censuses.
6. Coexistence with an intensive culture of channel catfish had no measurable influence upon the production of bass because no significant difference existed between final weights of bass stocked only with bluegills and bass stocked with bluegills and both caged and uncaged catfish.
7. In 1971, mortalities averaged 5.4 percent among the uncaged catfish, and only 1.0 percent among the caged populations.
8. Caged catfish populations attained the greatest total weight when sharing a pond with only uncaged catfish, but the uncaged catfish populations attained greatest weights when associated with bass and bluegills.
9. Weights of the uncaged catfish populations averaged 153.5 pounds (69.6 kilograms) heavier than the caged populations, and uncaged individuals outweighed caged individuals by an average of 0.29 pound (131.5 grams).
10. Final standing crops for the six populations of bluegills averaged 219.7 pounds per acre (246.3 kilograms per hectare), which was substantially higher than standing crops measured in any of a cross section of other unfertilized Illinois waters.
11. Final standing crops in our six populations of bass averaged 69.3 pounds per acre (77.7 kilograms per hectare), which was higher than the average for a cross section of other Illinois waters.
12. The data suggest that channel catfish can be produced in commercial quantities in ponds containing better-than-average standing crops of bass and bluegills without loss in production of any of the three intermixed species.
13. The combining of intensive cultures of channel catfish with fishable populations of bass and bluegills could retain, and perhaps even enhance, the recreational aspects of a pond while the pond was being used as a source of income.

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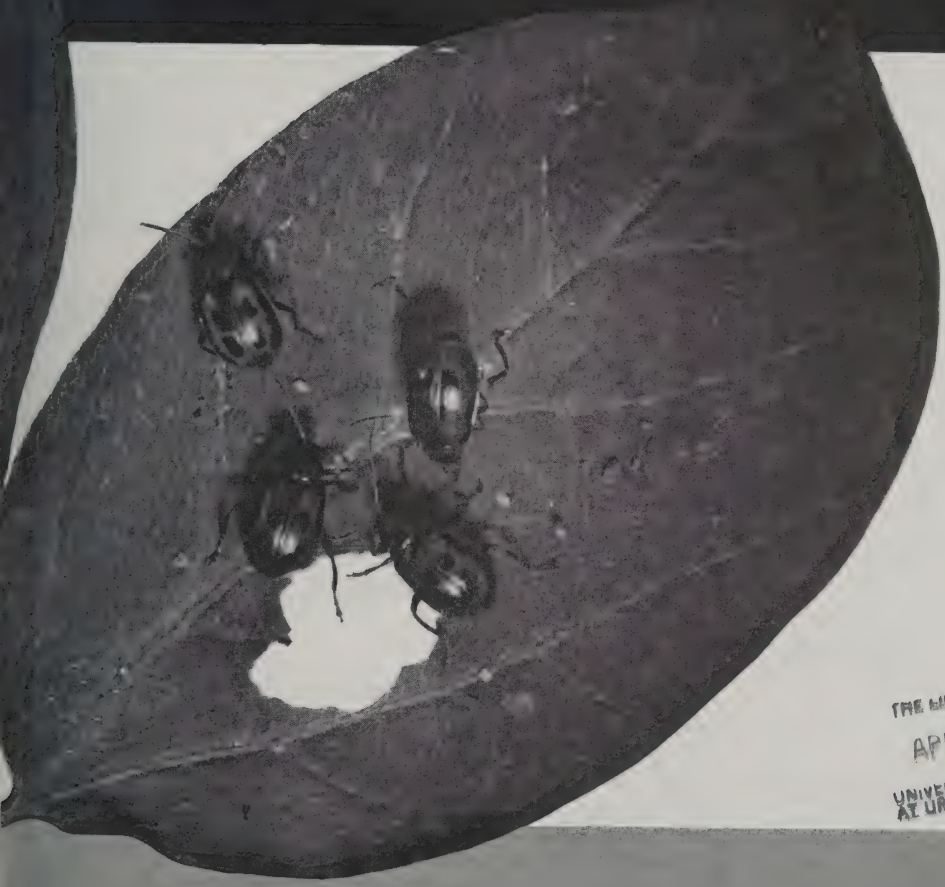
Biology

The Literature of Arthropods Associated with Soybeans

III. A BIBLIOGRAPHY OF THE BEAN LEAF BEETLES

Cerotoma trifurcata (Forster) and *C. ruficornis* (Olivier) (Coleoptera: Chrysomelidae)

M. P. NICHOLS • M. KOGAN • G. P. WALDBAUER



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The Literature of Arthropods Associated with Soybeans

III. A BIBLIOGRAPHY OF THE BEAN LEAF BEETLES *Cerotoma trifurcata* (Forster) and *C. ruficornis* (Olivier) (Coleoptera: Chrysomelidae)

M. P. Nichols, M. Kogan, and G. P. Waldbaue

Two species of the genus *Cerotoma* Chevrolat, 1837,[1] are important agricultural pests and have become significant elements of the arthropod fauna associated with soybeans in the New World. *C. trifurcata* (Forster, 1771)[2] is the only species of the genus known to attack soybeans in the continental United States, while *C. ruficornis* (Olivier, 1791)[3] occurs primarily south of the United States.

Both species are well defined taxonomically, and despite considerable variation in their color and pattern the synonymy is not extensive. The primary synonyms of *C. trifurcata* are *C. caminea* (Fabricius, 1801),[4] which appears frequently in the literature, and *C. fibulata* (Germar, 1824)[5]. Barber (1945)[6] lists *C. denticornis* (Fabricius, 1792)[7] and *C. sexpunctatus* (Horn, 1872)[8] as the synonyms of *C. ruficornis*. Hei zog (1968)[9] made a detailed study of the color varia tions of *C. trifurcata*.

The distribution of each species is known only i general terms. *C. trifurcata* is found from souther Canada to the Gulf states, extending from the Atla tic coast westward to South Dakota in the north an to Arizona in the south. It is also found in Puert Rico. *C. ruficornis* is widely distributed in the We Indies and, on the mainland, occurs in Florida an Texas and from Mexico to northern Venezuela.

Bean leaf beetles damage several growth stag of soybeans, with the amount of damage varying fro region to region according to the phenology of th beetles and their host plants. The larvae feed on th

1 See entry 97 in the bibliography.
2 See entry 121 in the bibliography.
3 See entry 256 in the bibliography.
4 See entry 114 in the bibliography.
5 See entry 130 in the bibliography.
6 See entry 32 in the bibliography.
7 See entry 113 in the bibliography.
8 See entry 161 in the bibliography.
9 See entry 154 in the bibliography.

This paper is published by authority of the State of Illino IRS Ch. 127, Par. 58.12. M. P. Nichols is a Research Associa International Programs and Studies, University of Illinois. I M. Kogan is an Associate Entomologist at the Illinois Natu History Survey and Associate Professor at the University Illinois College of Agriculture. Dr. G. P. Waldbauer is a P fessor of Entomology and of Agricultural Entomology at t University of Illinois.

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subterranean parts and adults feed on the foliage and sometimes on the green pods. The information outlined below is based largely on accounts of the behavior of *C. trifurcata.* However, it is likely that the behavior of *C. ruficornis* differs only in detail.

C. trifurcata has two or three complete generations per year throughout its geographic range. Thus, an abundance of adults may coincide with three stages of plant growth. In the Midwest, overwintered adults may invade soybean fields soon after germination and may destroy large numbers of seedlings. Replanting occasionally has been necessary. Adults of the first generation are usually present during the period of strong vegetative growth. They feed almost exclusively on the leaves, and economic damage due to feeding *per se* results only when populations are extremely high. However, *C. trifurcata* also transmits the bean pod mottle virus. The effect of this virus on yield is not clear, but there is evidence that when multiple infections occur it may have a synergistic relationship with the soybean mosaic virus. *C. ruficornis* is known to transmit the cowpea mosaic virus. Adults of the last generation may accumulate in late maturing fields and attack green pods. In such cases the yield is directly affected.

Intercrop relationships are an important factor to be considered in pest-management programs involving the bean leaf beetles. Isely (1942)[10] reported that in Arkansas enormous populations of adult *C. trifurcata* developed on soybeans. Snapbeans for the fall market were planted in midsummer and were still green when the early-planted soybeans were losing their leaves and nearing maturity. The smaller acreages of snapbeans were then suddenly flooded with large numbers of beetles emigrating from the soybean fields.

At least four additional species of *Cerotoma* are known to be associated with soybeans or other grain legumes in South America. *C. facialis* Erickson, 1847,[11] and *C. salvini* Baly, 1866,[12] are known from Panama, Colombia, and Peru; *C.* [*Andrector*] *ruficollis* (Fabricius, 1801)[13] and *C. unicornis* (Germar, 1824)[14] are known from Brazil. Published information on these species consists of little more than the original descriptions and listings in faunistic surveys and systematic catalogues. The pertinent literature on the Brazilian species up to December 1962 may be found in Silva et al. (1967)[15].

This bibliography follows closely the format and style of the two previous publications in this series.[16] Sources of the entries listed were primarily *Biological Abstracts, The Review of Applied Entomology Series A, Bio-Research Index, Biological and Agricultural Index, Index to the Literature of American Economic Entomology,* and references cited in articles and inquiries to researchers. All entries except No. 121 were examined. The references are listed alphabetically by author and numbered consecutively. The numbers are arranged in a table (see pages 8 and 9) according to subject and period of publication. A reference may be listed under more than one subject. References which apply to *C. trifurcata* are tabulated by number in lightface type. Those which apply to *C. ruficornis* follow and are in boldface type. References which refer to both species will appear twice under a heading.

Interested researchers are urged to consult the USDA *Cooperative Economic Insect Report* and the USDA *Insect Pest Survey Bulletin* for further information concerning *C. trifurcata.*

SIRIC (Soybean Insect Research and Information Center, Illinois Natural History Survey and University of Illinois at Urbana-Champaign) has developed a series of computer programs which make possible more detailed searches of the literature according to subject matter. All citations in this bibliography are stored on tape, and can be retrieved through a series of key words which define categories considerably more refined than those listed in the table on pages 8 and 9. The computerized information system greatly increases the usefulness of the printed bibliographies, and the two together are an important part of the effort of the Illinois Soybean Entomology Team to search out, compile, and organize for ready access the ever-increasing information on soybean entomology for the benefit of all professionals working in this area.

Abbreviations and complete titles of the sources which appear in the bibliographic entries are to be found in a listing at the end of the paper.

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TABLE OF REFERENCES BY SUBJECT AND PERIOD OF PUBLICATION

SUBJECT \ YEAR	1899 & PRIOR	1900-1909	1910's	1920's	1930's
TAXONOMY	56,97,114,121, 129,130,142,162, 163,194,195,257, 386. **97,113,114,129, 142,144,161,176, 177,179,256,352, 387,390.**		211.	197,391. **197,391,392.**	36,220.
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BEHAVIOR, INCLUDING FEEDING AND HOST SELECTION	57.	309.	190,199,310. **190.**	311.	109,173,220.
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PARASITES & PREDATORS		191.	212,252.	**221,405.**	109.
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PLANT RESISTANCE					
INSECTICIDAL CONTROL METHODS		27,153,158,254, 339,349.	206,353.	167,216,217,266.	39,40,89,11 **50,406.**
NONINSECTICIDAL CONTROL METHODS			212.		109.

1940's	1950's	1960's	1970's	SOYBEAN
22. **21,22.**	32,156,182,401. **32,143.**	93,402. **402.**		402. **402.**
281. **281.**	**143.**	154,268.	155,305,306,325.	
		154.	**155.** **340.**	
			186.	173,186,220.
208,242,243,270, 322. **262.**	25,244,245,246, 247,267,409.	78,224,248.		25,74,78,242,247, 267.
286.	347.	154.	53.	53.
170,209,232,346, 348,394. **21,262.**	7,9,32,288,289, 359. **29,32.**	11,35,116,224, 253,290,291,292, 293,360,363.	294.	7,9,11,35,44,74, 359,360,363.
			368.	368.
	124,267.	78.		78,109.
3,31,66,69,81,88, 100,146,174,207, 208,209,213,231, 237,240,241,243, 270,271,297,314, 322,327,334,336, 337,338,345,354. **4,19,275,278.**	6,8,9,65,82,83,84, 85,86,87,227,239, 244,245,246,247, 259,260,261,263, 288,289,328,335, 343,365,409. **51.**	11,12,13,37,112, 125,169,175,193, 224,229,230,238, 248,249,253,274, 287,290,291,292, 293,315,316,319, 330,360.	210,250,269,294, 317.	6,8,9,11,12,13,20, 26,30,37,38,44, 66,69,83,84,85, 86,87,109,147, 157,169,174,175, 193,207,208,210, 212,222,223,224, 226,227,229,230, 235,236,237,238, 239,240,241,247, 249,250,253,259, 260,261,263,269, 271,274,287,317, 321,322,323,328, 330,343,360,365, 394,409. **137,275.**
75,215,369. **75,76.**	17,18,54,77,122, 332. **54.**	90,102,302,318, 370,371,372,373, 374,376,377,379. **55,90,318,374.**	14,15,180,181, 192,234,324,325, 375,378,380. **92,127,192.**	14,15,180,234, 302,369,370,371, 375,377,379,380.
		185.	186.	185,186.
31,41,42,94,104, 105,106,118,141, 218,219,265,282, 297,298,327,341, 395,396,397. **276,277.**	5,9,24,47,95,96, 139,184,295,342, 398,399. **51.**	10,48,103,115, 228,272,273,303, 304,330,358,361, 362.	16,23,53,73,101, 123,171,196,233, 264,283,299,306, 350,357.	5,9,10,16,23,47, 48,53,104,105, 106,115,123,196, 218,233,264,272, 273,283,303,304, 327,330,342,350, 357,358.
				212.

for resistance to the bean leaf beetle, *Cerotoma trifurcata* (Forster), the southern green stink bug, *Nezara viridula* (Linneaus), and the soybean looper, *Pseudoplusia includens* (Walker). Ph. D. Diss., Louisiana State University, Baton Rouge. 82 p. illus. refs.

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PERIODICAL ABBREVIATIONS

Advan. Virus Res. — Advances in Virus Research.
Agron. Trop. (Maracay) — Agronomia Tropical (Marac
Ala. Agr. Exp. Sta. Leafl. — Alabama Agricultural Exp ment Station Leaflet.
Ala. Geol. Surv. Monogr. — Alabama Geological Su Monograph.
Amer. Midland Natur. — American Midland Naturalist
An. Soc. Espan. Hist. Natur. — Anales de la Soci Española de Historia Natural.
Anal. Chem. — Analytical Chemistry.
Ann. Appl. Biol. — Annals of Applied Biology.
Ann. Mag. Natur. Hist. — Annals and Magazine of Nat History.
Ann. Soc. Entomol. Fr. — Annales de la Société E mologique de France.
Annu. Rep. Off. Exp. Stas. — Annual Report of the Offi Experiment Stations.
Annu. Rev. Entomol. — Annual Review of Entomology.
Arch. Naturgesch. — Archiv für Naturgeschichte.
Ariz. Agr. Ext. Serv. Circ. — Arizona Agricultural Exte Service Circular.
Arkansas Agr. Exp. Sta. Bull. — Arkansas Agricultura periment Station Bulletin.

Arkansas Agr. Ext. Serv. Circ. — Arkansas Agricultural Extension Service Circular.
Arkansas Agr. Ext. Serv. Leafl. — Arkansas Agricultural Extension Service Leaflet.
Arkansas Farm Res. — Arkansas Farm Research.
Auburn Univ. Coop. Ext. Serv. Circ. — Auburn University Cooperative Extension Service Circular.
Biol. Cent.-Amer. — Biologia Centrali-Americana.
Biol. Rev. (Cambridge) — Biological Reviews and Biological Proceedings, Cambridge Philosophical Society.
Bull. Brooklyn Entomol. Soc. — Bulletin of the Brooklyn Entomological Society.
Can. Entomol. — Canadian Entomologist.
Caribb. Res. Coun. Crop Inq. Ser. — Caribbean Research Council, Crop Inquiry Series.
Clemson Agr. Coll. Ext. Serv. Bull. — Clemson Agricultural College Extension Service Bulletin.
Clemson Agr. Coll. Ext. Serv. Circ. — Clemson Agricultural College Extension Service Circular.
Clemson Univ. Agr. Ext. Serv. Circ. — Clemson University Agricultural Extension Service Circular.
Conn. Agr. Exp. Sta. Bull. — Connecticut Agricultural Experiment Station Bulletin.
Conn. State Geol. Natur. Hist. Surv. Bull. — Connecticut State Geological and Natural History Survey Bulletin.
Coop. Econ. Insect Rep. — Cooperative Economic Insect Report.
Cornell Ext. Bull. — Cornell Extension Bulletin.
Cornell Univ. Agr. Exp. Sta. Mem. — Cornell University Agricultural Experiment Station Memoir.
Del. Agr. Exp. Sta. Annu. Rep. — Delaware Agricultural Experiment Station Annual Report.
Del. Agr. Exp. Sta. Bull. — Delaware Agricultural Experiment Station Bulletin.
Del. Agr. Ext. Serv. Ext. Bull. — Delaware Agricultural Extension Service Extension Bulletin.
Emory Univ. Mus. Bull. — Emory University Museum Bulletin.
Entomol. Arb. — Entomologische Arbeiten.
Entomol. News — Entomological News.
Environ. Entomol. — Environmental Entomology.
Ext. Entomol. — The Extension Entomologist (USDA).
Farm Quart. — The Farm Quarterly.
Farm Tech. — Farm Technology.
Fla. Agr. Exp. Sta. Annu. Rep. — Florida Agricultural Experiment Station Annual Report.
Fla. Agr. Exp. Sta. Bull. — Florida Agricultural Experiment Station Bulletin.
Fla. Entomol. — Florida Entomologist.
Ga. Coop. Ext. Serv. Leafl. — Georgia Cooperative Extension Service Leaflet.
Ga. Exp. Sta. Annu. Rep. — Georgia Experiment Station Annual Report.
Ga. Exp. Sta. Bull. — Georgia Experiment Station Bulletin.
Ga. State Bd. Entomol. Bull. — Georgia State Board of Entomology Bulletin.
Ga. State Coll. Agr. Ext. Div. Bull. — Georgia State College of Agriculture Extension Division Bulletin.
Ill. Agr. Exp. Sta. Circ. — Illinois Agricultural Experiment Station Circular.
Ill. Agr. Ext. Serv. Circ. — Illinois Agricultural Extension Service Circular.
Ill. Coop. Ext. Serv. Circ. — Illinois Cooperative Extension Service Circular.
Ill. Veg. Growers Bull. — Illinois Vegetable Growers Bulletin.
Insect Pest Surv. Bull. — Insect Pest Survey Bulletin (USDA).
Iowa Agr. Exp. Sta. Rep. Agr. Res. — Iowa Agricultural Experiment Station Report on Agricultural Research.
Iowa State Coll. J. Sci. — Iowa State College Journal of Science.
Iowa State Univ. Coop. Ext. Serv. — Iowa State University Cooperative Extension Service.
J. Agr. Res. — Journal of Agricultural Research.
J. Agr. Univ. P. R. — Journal of Agriculture of the University of Puerto Rico.
J. Amer. Soc. Agron. — Journal of the American Society of Agronomy.
J. Dep. Agr. P.R. — Journal of the Department of Agriculture of Porto Rico.
J. Econ. Entomol. — Journal of Economic Entomology.
J. Ga. Entomol. Soc. — Journal of the Georgia Entomological Society.
J. Kans. Entomol. Soc. — Journal of the Kansas Entomological Society.
J. N. Y. Entomol. Soc. — Journal of the New York Entomological Society.
Jamaica Dep. Agr. Annu. Rep — Annual Report of the Jamaica Department of Agriculture.
Jamaica Dep. Agr. Entomol. Bull. — Department of Agriculture, Jamaica, Entomological Bulletin.
Kans. Agr. Exp. Sta. Annu. Rep. — Annual Report of the Kansas Agricultural Experiment Station.
Kans. State Bd. Agr. Rep. — Report of the Kansas State Board of Agriculture.
Ky. Agr. Exp. Sta. Annu. Rep. — Kentucky Agricultural Experiment Station Annual Report.
Ky. Agr. Ext. Div. Circ. — Kentucky Agricultural Extension Division Circular.
La. Agr. Exp. Sta. Annu. Rep. — Louisiana Agricultural Experiment Station Annual Report.
La. Agr. Exp. Sta. Bull. — Louisiana Agricultural Experiment Station Bulletin.
La. Coop. Ext. Serv. Publ. — Louisiana Cooperative Extension Service Publication.
La. State Crop Pest Comm. Circ. — Louisiana State Crop Pest Commission Circular.
Md. Agr. Exp. Sta. Bull. — Maryland Agricultural Experiment Station Bulletin.
Md. Coop. Ext. Serv. Ext. Bull. — Maryland Cooperative Extension Service Extension Bulletin.
Md. Ext. Serv. Bull. — Maryland Extension Service Bulletin.
Mich. Entomol. — Michigan Entomologist.
Miss. Agr. Coll. Ext. Dep. Bull. — Mississippi Agricultural College Extension Department Bulletin.
Miss. Agr. Coll. Ext. Dep. Circ. — Mississippi Agricultural College Extension Department Circular.
Miss. Agr. Exp. Sta. Annu. Rep. — Mississippi Agricultural Experiment Station Annual Report.
Miss. Agr. Ext. Serv. Circ. — Mississippi Agricultural Extension Service Circular.
Miss. Agr. Forest. Exp. Sta. Annu. Rep. — Mississippi Agricultural and Forestry Experiment Station Annual Report.
Miss. State Univ. Coop. Ext. Serv. Inform. Sheet — Mississippi State University Cooperative Extension Service Information Sheet.
Mo. Agr. Exp. Sta. Bull. — Missouri Agricultural Experiment Station Bulletin.
Mo. Agr. Exp. Sta. Circ. — Missouri Agricultural Experiment Station Circular.
Mo. Agr. Exp. Sta. Res. Bull. — Missouri Agricultural Experiment Station Research Bulletin.
Mo. Agr. Ext. Serv. Circ. — Missouri Agricultural Extension Service Circular.
Mo. Agr. Ext. Serv. Fold. — Missouri Agricultural Extension Service Folder.
N. C. Agr. Exp. Sta. Annu. Rep. — North Carolina Agricultural Experiment Station Annual Report.
N. C. Agr. Exp. Sta. Bull. — North Carolina Agricultural Experiment Station Bulletin.
N. C. Agr. Ext. Serv. Ext. Circ. — North Carolina Agricultural Extension Service Extension Circular.
N. C. State Univ. Agr. Ext. Serv. Insect Notes — North Carolina State University, Agricultural Extension Service, Insect Notes.
N. J. Agr. Exp. Sta. Annu. Rep. — New Jersey Agricultural Experiment Station Annual Report.
N. J. State Bd. Agr. Annu. Rep. — New Jersey State Board of Agriculture Annual Report.
N. Mex. Agr. Exp. Sta. Bull. — New Mexico Agricultural Experiment Station Bulletin.
N. Y. State Agr. Exp. Sta. Tech. Bull. — New York State Agricultural Experiment Station Technical Bulletin.

N. Y. State Mus. Sci. Serv. Bull. — New York State Museum and Science Service Bulletin.
Nebr. Agr. Ext. Serv. — Nebraska Agricultural Extension Service.
Ohio Agr. Exp. Sta. Bull. — Ohio Agricultural Experiment Sta. Bulletin.
Ohio Biol. Surv. Bull. — Ohio Biological Survey Bulletin.
Ohio J. Sci. — Ohio Journal of Science.
Ohio State Univ. Agr. Coll. Ext. Serv. Bull. — Ohio State University Agricultural College Extension Service Bulletin.
Okla. Agr. Exp. Sta. Bull. — Oklahoma Agricultural Experiment Station Bulletin.
Okla. Agr. Ext. Div. Circ. — Oklahoma Agricultural Extension Division Circular.
Okla. Farmer-Stockman — Oklahoma Farmer-Stockman.
P. R. Agr. Exp. Sta. Annu. Rep. — Annual Report of the Puerto Rico Agricultural Experiment Station.
P. R. Agr. Exp. Sta. Rep. — Report of the Porto Rico Agricultural Experiment Station.
P. R. Bd. Commr. Agr. Rep. — Report of the Board of Commissioners of Agriculture of Porto Rico.
P. R. Estac. Exp. Ins. Bol. — Puerto Rico Estacion Experimental Insular Boletin.
P. R. Fed. Exp. Sta. Rep. — Report of the Federal Experiment Station in Puerto Rico.
P. R. Ins. Exp. Sta. (Rio Piedras) Annu. Rep. — Porto Rico Insular Experiment Station (Rio Piedras) Annual Report.
Phytopathol. Z. — Phytopathologische Zeitschrift.
Plant Dis. Rep. — Plant Disease Reporter.
Proc. Acad. Natur. Sci. Philadelphia — Proceedings of the Academy of Natural Sciences of Philadelphia.
Proc. Calif. Acad. Sci. — Proceedings of the California Academy of Science.
Proc. Entomol. Soc. Wash. — Proceedings of the Entomological Society of Washington.
Proc. Indiana Acad. Sci. — Proceedings of the Indiana Academy of Science.
Proc. N. Cent. Br. Entomol. Soc. Amer. — Proceedings of the North Central Branch of the Entomological Society of America.
Proc. Ohio State Hort. Soc. Annu. Meet. — Proceedings of the Ohio State Horticultural Society Annual Meeting.
Proc. Zool. Soc. London — Proceedings of the Zoological Society of London.
Purdue Univ. Coop. Ext. Serv. Dep. Entomol. Publ. — Purdue University Cooperative Extension Service, Department of Entomology Publication.
Rep. Md. State Hort. Soc. Annu. Meet. — Report of the Maryland State Horticultural Society Annual Meeting.
Rep. U. S. Commr. Agr. — Report of the United States Commissioner of Agriculture.
Res: Farming — Research and Farming.
Rev. Agr. (Cuba) — Revista de Agricultura (Cuba).
Rev. Agr. P. R. — Revista de Agricultura de Puerto Rico.
S. C. Agr. Exp. Sta. Annu. Rep. — South Carolina Agricultural Experiment Station Annual Report.
S. C. Agr. Exp. Sta. Bull. — South Carolina Agricultural Experiment Station Bulletin.
S. C. Agr. Exp. Sta. Circ. — South Carolina Agricultural Experiment Station Circular.
Santiago de las Vegas, Cuba Estac. Exp. Agron. Bol. — Santiago de las Vegas, Cuba, Estacion Experimental Agronomica Boletin.
Santiago de las Vegas, Cuba Estac. Exp. Agron. Circ. — Santiago de las Vegas, Cuba, Estacion Experimental Agronomica Circular.
Santiago de las Vegas, Cuba Estac. Exp. Agron. Informe Dep. Entomol. Fitopatol. — Santiago de las Vegas, Cuba, Estacion Experimental Agronomica, Informe del Departmento de Entomologia y Fitopatologia.
Smithson. Misc. Collect. — Smithsonian Miscellaneous Collection.
Soybean Dig. — Soybean Digest.
Tenn. Agr. Exp. Sta. Annu. Rep. — Tennessee Agricultural Experiment Station Annual Report.
Tenn. Agr. Exp. Sta. Bull. — Tennessee Agricultural Experiment Station Bulletin.
Tenn. Agr. Exp. Sta. Circ. — Tennessee Agricultural Experiment Station Circular.
Tenn. Agr. Ext. Serv. Publ. — Tennessee Agricultural Extension Service Publication.
Tex. Agr. Exp. Sta. Bull. — Texas Agricultural Experiment Station Bulletin.
Trans. Amer. Entomol. Soc. — Transactions of the American Entomological Society.
Trans. Entomol. Soc. London — Transactions of the Entomological Society of London.
Trans. Kans. Acad. Sci. — Transactions of the Kansas Academy of Science.
Trop. Agr. — Tropical Agriculture.
U.S. Dep. Agr. Agr. Handb. — United States Department of Agriculture, Agriculture Handbook.
U.S. Dep. Agr. Bull. — United States Department of Agriculture Bulletin.
U.S. Dep. Agr. Bur. Biol. Surv. Bull. — United States Department of Agriculture, Bureau of Biological Survey Bulletin.
U.S. Dep. Agr. Bur. Entomol. Plant Quar. E. — United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, E Series.
U.S. Dep. Agr. Bur. Entomol. Plant Quar. News Let. — United States Department of Agriculture, Bureau of Entomology and Plant Quarantine News Letter.
U.S. Dep. Agr. Bur. Entomol. Rep. Entomol. — United States Department of Agriculture, Bureau of Entomology, Report of the Entomologist.
U.S. Dep. Agr. Dep. Circ. — United States Department of Agriculture, Department Circular.
U.S. Dep. Agr. Div. Entomol. Bull. (n.s.) — United States Department of Agriculture, Division of Entomology Bulletin (New series).
U.S. Dep. Agr. Farmers Bull. — United States Department of Agriculture Farmers' Bulletin.
U.S. Dep. Agr. Home Gard. Bull. — United States Department of Agriculture Home and Garden Bulletin.
U.S. Dep. Agr. Misc. Publ. — United States Department of Agriculture, Miscellaneous Publication.
U.S. Dep. Agr. Rep. Chf. Bur. Entomol. Plant Quar. United States Department of Agriculture, Report of the Chief of the Bureau of Entomology and Plant Quarantine.
U.S. Dep. Agr. Tech. Bull. — United States Department of Agriculture Technical Bulletin.
U.S. Dep. Agr. Yearb. — United States Department of Agriculture Yearbook.
U.S. Dep. Agr. Yearb. Agr. — United States Department of Agriculture, Yearbook of Agriculture.
U.S. Nat. Mus. Bull. — United States National Museum Bulletin.
Va. Polytech. Inst. Agr. Ext. Serv. Circ. — Virginia Polytechnic Institute Agricultural Extension Service Circular.
Va. Polytech. Inst. Ext. Div. Contr. Ser. — Virginia Polytechnic Institute Extension Division Control Series.
Va. Truck Exp. Sta. Bull. — Virginia Truck Experiment Station Bulletin.
W. Va. Agr. Exp. Sta. Bull. — West Virginia Agricultural Experiment Station Bulletin.
Zool. Jahrb. Abt. Syst. Okol. Geogr. Tiere — Zoologische Jahrbücher Abteilung für systematik Ökologie und Geographie der Tiere.

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Biology

ILLINOIS BIRDS: Tyrannidae

RICHARD R. GRABER, JEAN W. GRABER, ETHELYN L. KIRK

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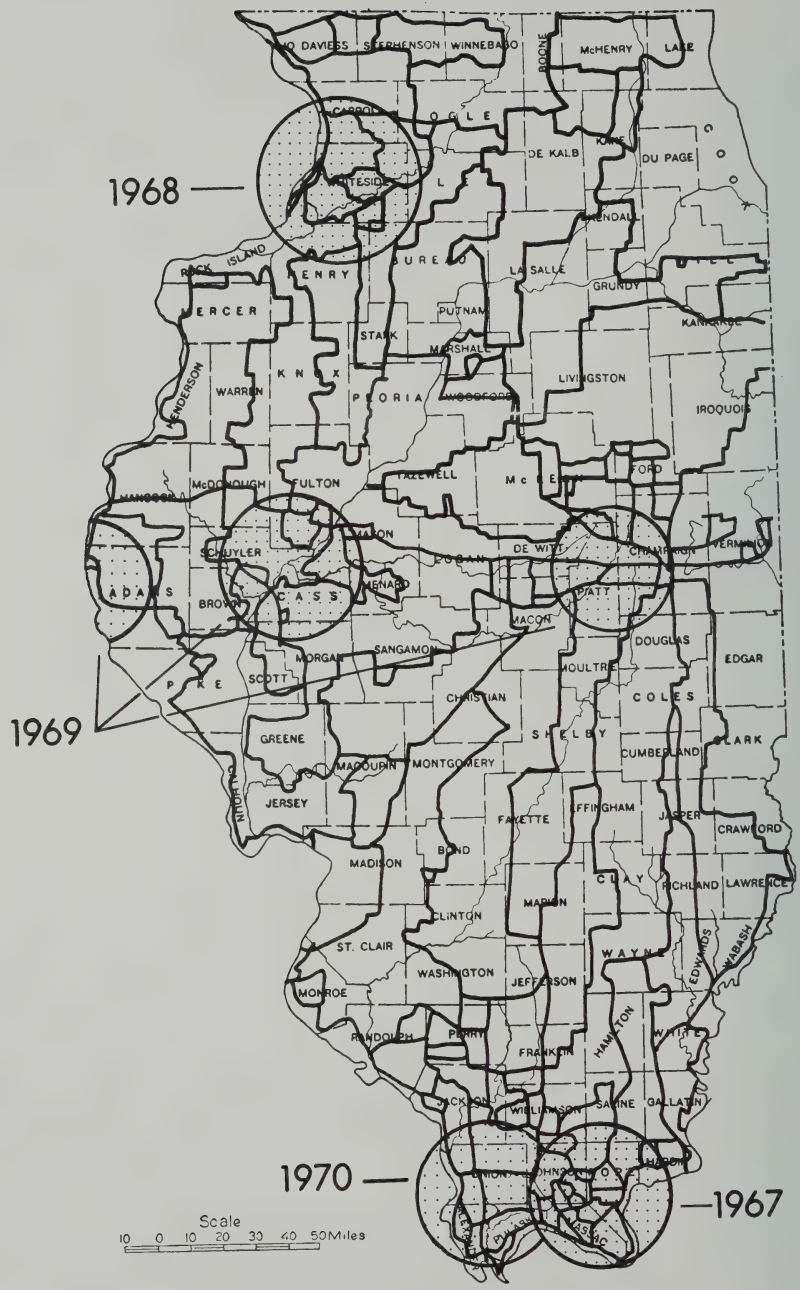

Fig. 1. — Routes traveled (1957-1972) to study breeding distribution of Illinois birds. The encircled areas were special study areas where daily censuses of migrants and nesting populations of birds were carried out, 1967-1970.

LINOIS BIRDS: Tyrannidae

Richard R. Graber, Jean W. Graber, and Ethelyn L. Kirk

THIS IS THE FIFTH in a series of papers designed especially to bring together and nmarize the widely scattered and often almost ccessible published data on Illinois birds. The papers o include unpublished information gained from the hors' continuing field studies, and information ntributed by a number of excellent observers from eral areas of the state.

Much of the quantitative data presented on migration l nesting represents special study areas (Fig. 1). Our icies on interpretation and presentation of data have n discussed in the earlier papers (Graber et al. 1970, 1, 1972, 1973), each of which deals with a different ily of birds. Two points concerned with the sentation of data that were not considered in the lier papers deserve mention here. Unless otherwise ed, references to time of day are to central standard e. Also unless otherwise stated, measurements of wing gth refer to the wing chord, and measurements of bills r to the distance from the anterior edge of the nostril he tip of the bill.

This paper deals with the flycatchers of Illinois, a up that presents some particularly difficult problems identification. Though the species are biologically inctive, some of them, especially species of the genus *pidonax,* are all but identical in appearance. Five *pidonax* flycatchers (yellow-bellied, Acadian, willow, r, and least) occur regularly in Illinois, and there are mber of errors in the Illinois ornithological literature probably stem from misidentification of these and r even less similar flycatchers. Except for the ow-bellied flycatcher, the Illinois *Empidonax* atchers are not identifiable in the field unless they or are associated with a nest and a particular itat. Even the yellow-belly can easily be confused other *Empidonax,* particularly in the fall (Mengel 2), but because we have studied many collected imens of *Empidonax* flycatchers we believe we can lly identify the yellow-bellied flycatcher in the field if ee the bird at close range. Such field identifications tentative at best, however, and it is not easy to tify *Empidonax* flycatchers even when they are in l (Phillips et al. 1966).

n our censuses of the migration we counted inging (silent) *Empidonax* flycatchers, other than w-bellies, simply as unidentified *Empidonax.* ing birds or collected specimens were counted under ppropriate species, and even with yellow-bellies most ir identifications were based on songs or call notes. identified many more *Empidonax* in the spring than in the fall, because birds sing more in the spring than fall. Other methods of study, such as bird netting, are essential for this group particularly. In dealing with published records, we have generally accepted identifications of *Empidonax* flycatchers as given unless the record seemed clearly in error. Such errors are discussed briefly in the species accounts. Where problematical identifications were involved, we based our judgements, to the extent possible, on data from collected specimens. The available collections are woefully inadequate.

Recently the American Ornithologists' Union Committee on Classification and Nomenclature (1973) recognized the existence of two species of Traill's flycatchers. The populations which for many years had been considered one species, Traill's flycatcher (*Empidonax traillii*), are now considered to comprise two distinct species — the willow flycatcher (*E. traillii*) and the alder flycatcher (*E. alnorum*). The two forms differ slightly in song and nesting habits (Stein 1963), but are so similar in appearance that many specimens (in hand) cannot be specifically identified with certainty. Despite the extreme subtlety of the differences between the two forms, we have followed the A.O.U. Committee's new nomenclature, where applicable, but have also used the old name (Traill's flycatcher) in reference to the complex of populations when specific identification was not possible.

For the flycatchers, as for other groups, vocalizations are interesting but also very difficult to treat in writing. Consequently we have placed little emphasis on this aspect of Illinois ornithology. The phonetic interpretations of vocalizations which we and others use may be more misleading than helpful, as there are perhaps as many interpretations of a song or a call as there are interpreters. For example, we have never been able to hear the commonly used phonetic "fitz-bew" as the song of the willow flycatcher. To our ears there are definite "rrr" sounds in the song which the phrase "fitz-bew" simply does not convey. Audiograms of bird vocalizations are more precise, and unquestionably superior for technical studies of song, but they are probably of little or no more help than phonetics to students who have never heard the song or call. There is no real substitute for hearing and learning the song in the field.

For help, particularly with the acquisition of data for this report on the flycatchers, we especially thank Mrs. William Carroll of Woodstock, James and Loraine Funk of Liberty, L. Barrie Hunt of Eastern Illinois University, Richard A. Anderson of St. Louis, Peter C. Petersen of Davenport, David Hayward of Carbondale, Lawrence G. Balch of Chicago, Mark Swan of Oregon, Michael D. Morrison of Sparta, Noel P. Lane of Edwardsville, William G. George of Southern Illinois University,

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Vernon M. Kleen of the Illinois Department of Conservation, and H. David Bohlen of the State Museum at Springfield.

Virginia Engelhard of the Cornell University Laboratory of Ornithology kindly provided us with an audio spectrogram of an alder flycatcher song recorded in Illinois, and compared the Illinois record with records in the Cornell collection.

Dr. Glen C. Sanderson provided valuable criticism of the original draft, and the final manuscript was edited by O. F. Glissendorf.

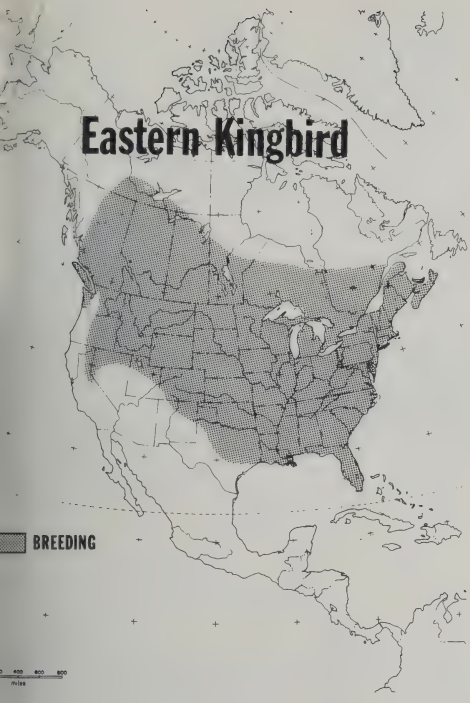
EASTERN KINGBIRD (*Tyrannus tyrannus*)

(Fig. 2 and 3)

Spring Migration

In tropical latitudes the migrations of ea kingbirds are often spectacular diurnal moven involving large flocks of birds (Skutch, in Bent 1 Youngworth (1950) observed similar migration kingbirds in August in western Iowa, but the migrati this species has apparently never been witnesse Illinois. Both Cooke (1888) and Gault (1898) inf

Fig. 2. — Eastern kingbird at its nest in a winged elm (*Ulmus alata*). Photo taken 5 miles north of Golconda in Pope County.



ig. 3. — General distribution of the eastern kingbird. The ned range may include large sections in which populations of the es are thin or even absent because of the nature of the terrain and ity of suitable habitat.

the spring migration of kingbirds in Illinois was urnal. In Pope County on May 5, 1967 we witnessed may have been a migration arrival, when kingbirds enly apeared about 11:00 a.m. in areas where there been none earlier.

The first few eastern kingbirds begin to appear in ern Illinois about mid-April, and in centtral and ern Illinois in late April (Fig. 4). Adcock's (1922) h 21 record for central Illinois is either erroneous or dental. Even records as early as April 8-10 (Cooke , Widmann 1907, Kleen & Bush 1972*b*) are ordinary and most observers do not detect the es until about May 1. Peak numbers of kingbirds n southern Illinois by May 8, and central and ern Illinois about May 20 (Fig. 4). In northern and al Illinois the migration probably extends into the week of June.

n 20 years of observation (1903-1922) in east-central is, Smith's (1930) earliest spring record for the rn kingbird was April 20, and the median arrival was April 27. A more recent 25-year record (to 1971) rival dates for kingbirds in west-central Illinois by ne and James Funk (personal communication) slightly earlier arrivals — the earliest being April d the median date April 25.

During the peak of migration kingbirds are often encountered in flocks of 10-40 or more birds. Though they are usually perched on fences and power lines or in trees, on cool days it is not uncommon to find them on the ground, particularly on plowed fields (Hancock 1888, Graber unpublished notes).

Distribution

The general distribution of the eastern kingbird is shown in Fig. 3. For such a conspicuous species there are surprisingly few actual nesting records for Illinois, but the June distribution indicates a fairly uniform nesting population throughtout the state (Fig. 5). In addition to plotted records on the map, there are recent June records (no specific locality given) for Jersey and Monroe counties (personal communication from D. Anderson), and there are specimens establishing old nesting records for two counties — Winnebago County (U.S. National Museum specimens), and Warren County (Chicago Museum of Natural History specimens).

Nesting Habitats and Populations

The eastern kingbird could be characterized as a savannah species, nesting in a variety of woody cover, surrounded by or adjacent to open country, from farmsteads to forest edge. Pastures, shrub areas, and orchards have been considered favorite habitats (Graber & Graber 1963, Ridgway 1887, Nehrling 1883). Population densities in suitable habitats vary from about two to nine kingbirds per 100 acres (Table 1). In a study of hedgerows in Ford County, we found only two pairs of kingbirds in about 5 miles of roadside hedge. In southern Illinois Brewer (1958) found that the younger successional growths of trees and shrubs (6-20 years) after strip mining had kingbirds, whereas an older stand (21-24 years) did not.

Barnes (1890) believed that the kingbird was not particular in its choice of nest sites. Both Barnes (1890, 1897) and Coursen (1947) found nests in dead trees standing in water, and other nests over water were found in live willows. Gates (1911) considered the kingbird to be a bottomland species, but there are no population measurements to show whether the species has a definite preference for lowland or upland habitats. Kingbirds definitely nest in both situations. Most of the recorded nests in Illinois were found in apple trees (*Malus*), though oaks (*Quercus*), willows (*Salix*), and osage orange (*Maclura pomifera*) were also commonly used as nest sites. Heights of nests have varied from 3 to 40 feet, most commonly from 10 to 20 feet.

Swink's (1960) study of perching sites of kingbirds also gives an impression of the species' habitat. The most frequently observed perching sites were telephone wires (11.5 percent), fences (8.5 percent), various species of oaks (11 percent), apples (8.5 percent), willows (8.5 percent), and cottonwoods, *Populus deltoides,* (4.5 percent).

Kingbirds show some tolerance of humans. Ridgway (1915) had a pair on 8 acres of suburban residential area

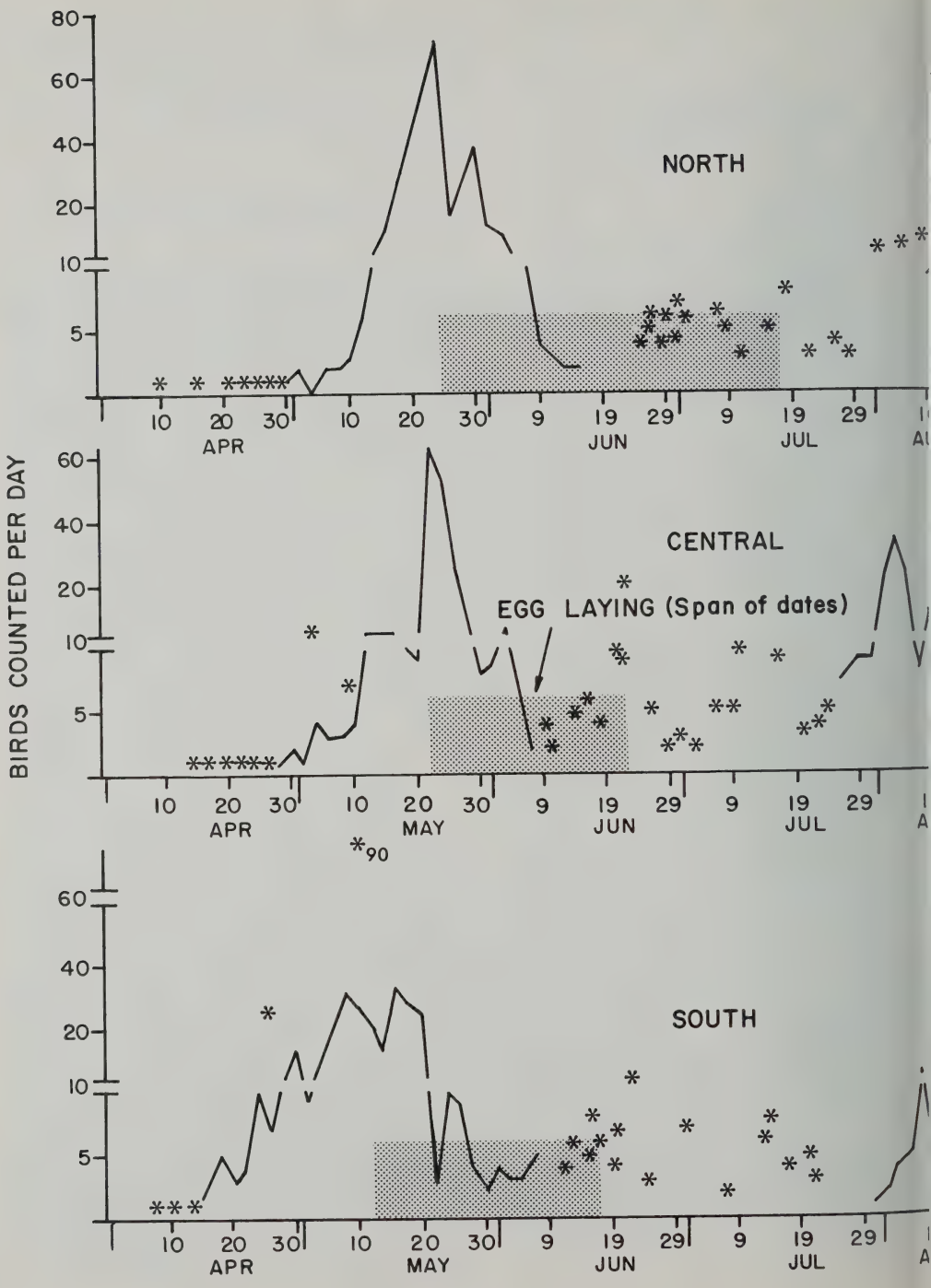
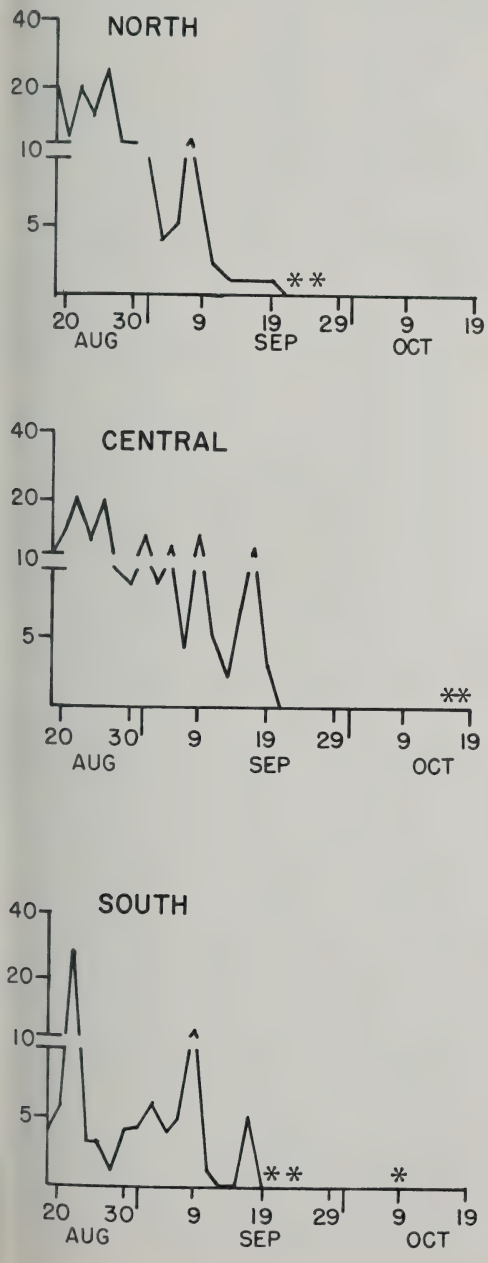

BIRDS COUNTED PER DAY
NORTH
CENTRAL
SOUTH
EGG LAYING (Span of dates)
80
60
40
20
10
5
10 20 30 10 20 30 9 19 29 9 19 29
APR
JUN
JUL
60
40
20
10
5
10 20 30 10 20 30 9 19 29 9 19 29
APR
MAY
JUN
JUL
*90
60
40
20
10
5
10 20 30 10 20 30 9 19 29 9 19 29
APR
MAY
JUN
JUL

Fig. 4. — Egg-laying and migration seasons of the eastern kingbird different areas of the state (see Fig. 1). Spring and fall graph lines 57-1970) show highest daily count of each 2 days (left scale). Asterisk bols represent counts made in other years or by other observers. ded areas show the span of dates during which egg laying has been orded.



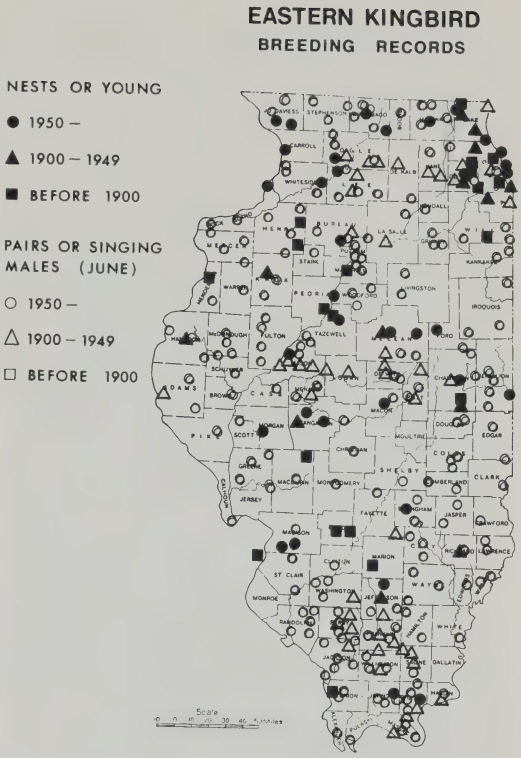


Fig. 5. — Breeding records for the eastern kingbird in Illinois. Singing male records cover the period June 1 to early July.

in Olney, but we know of no significant recent populations in urban habitat. Eiseman & Shank (1962) witnessed a nesting attempt by kingbirds in Chicago that was aborted apparently because of the commotion of human traffic.

From the statewide censuses of birds, we concluded that the state population of eastern kingbirds declined about 50 percent between 1907 and 1957, and that the loss was particularly great in southern Illinois (Graber & Graber 1963). We attributed the decline to large acreage losses of two important kingbird habitats — pastures and orchards. Eifrig (1937) also believed the kingbird population was declining, but attributed the change to reduced fly populations.

No territories of kingbirds have been measured in Illinois. The species is renowned for its aggressive behavior toward some other birds, including species of hawks, crows (*Corvus brachyrhynchos*), nighthawks (*Chordeiles minor*), red-winged blackbirds (*Agelaius phoeniceus*), and others (Ridgway 1889, Hankinson 1915, Musselman 1933, Back 1934-35). It is also surprisingly tolerant of some other species. The orchard oriole (*Icterus spurius*) sometimes nests in the same tree with the eastern kingbird in southern Illinois. There are

TABLE 1. — Breeding populations of eastern kingbirds in various Illinois habitats.

Habitat	Acres	Birds Per 100 acres[a]	Years	Type of Census	Region or County	Reference
Orchard	45	7	1907-1909	Strip	South	Graber & Graber 196
	78	4	1957-1958		South	
Shrub areas	32	9	1957-1958	Strip	North	Graber & Graber 196
	50	8			Central	
	129	1			South	
Late shrub	21	4	1966	Nest	Vermilion (C)	Karr 1968
Swampy prairie	67	9	1941	Nest	Sangamon (C)	Robertson 1941
	64	3	1942		Sangamon (C)	Robertson 1942*a*
Pastureland	193	5	1909	Strip	North	Graber & Graber 196
	442	3	1907-1909		Central	
	882	2			South	
	279	6	1957-1958		North	
	172	2			Central	
Upland second growth hardwoods	56	4	1942	Nest	Sangamon (C)	Robertson 1942*b*

[a] All figures were converted to read birds per 100 acres (territorial males or nests X 2).

no referenes on intraspecific aggression or spacing of kingbirds.

Nesting Cycle

The Illinois literature is essentially devoid of information on the nesting cycle of the eastern kingbird, and we can add little. Egg laying begins as early as May 12 in southern Illinois, and lasts at least through July 17 in the north (Fig. 4). Bent (1942) gives May 2 as an egg date in Illinois, but we do not know the source or locality for this record.

Data on 34 nests from the Illinois literature and our own field notes show clutch sizes for the kingbird as follows: 6 eggs — 9 percent, 5 eggs — 12 percent, 4 eggs — 41 percent, and 3 eggs — 38 percent. As most of these were nests without complete histories, the clutch data are crude. Better clutch data are needed particularly in view of the number of reports of nests with only one or two young. The implication is that this species has either low hatchability, or an unusually high loss of eggs or young even in successful nests.

There have been no measurements of the incubation period in Illinois. Nestling life at one nest in central Illinois was 13 days (Finley 1917), but this may represent the short extreme, as, in general, flycatchers tend to remain in the nest as long as possible. Finley (1917) also studied feeding rates of nestlings. Between 4:15 a.m. and 8:00 p.m. the adult birds made 163 trips to a nest with three young about 6 days old. Peak rates of feeding came at 6:00-7:00 a.m. and 5:00-6:00 p.m. and the lowest rate was at noon. The food of nestlings has not been recorded. We doubt Eaton's (1878) statement that kingbirds raise two broods in northern Illinois, but there are insufficient data to settle the question.

In view of the kingbird's aggressive nature, it is surprising that the species is ever parasitized by cowbirds (*Molothrus ater*), but we know of two instances in which Illinois kingbird nests were parasitized. A nest collected on June 11, 1885 by Elmer Pierce near Meacham (DuPage County), Illinois contained two cowbird eggs. A nest found July 7, 1967 near Havana (Mason Cou Illinois held one large cowbird, which probably fl successfully.

Fall Migration

The fall migration of kingbirds, as in the spring apparently never been witnessed in Illinois. Youngw (1950) observation of diurnal migration of kingbi Iowa is possibly indicative that the same kir migration occurs in Illinois. The migration that h starting early in the morning of August 28, lasted 5 and involved loose flocks of from 40 to nearly kingbirds flying southwest. Other large flights have seen in Iowa (Brown 1962). If such specta migrations occur in Illinois, why have they undetected? Another observation is indicative of migration of kingbirds in Illinois, for among hundr night migrants killed at a television tower in Sang County on the night of September 16-17, 1958 the a least one kingbird (Parmalee & Parmalee 1959).

Just when the fall migration begins is also unk There is evidence of some movement of kingbi early as July (Nolan 1956). Our fall counts show v peaks in August and early September, but consistent from region to region (Fig. 4). It i impression that notable kingbird migrations often between August 20 and 25, and September 6 and mid-September kingbirds have essentially disapp from Illinois. October records are probably excep even for the southern Illinois area (Anderson 1966 the latest fall records known to us were those of seen October 17, 1906 by Alfred Gross (unpub notes) and one seen on October 16, 1971 (Kleen & 1972*a*), both in west-central Illinois.

The ratio of the spring to fall counts of kingbi Illinois does not account for any productivit northern and central Illinois the spring-fall rati almost exactly even, and in the south the ratio was four kingbirds in the spring to one in the fall. figures suggest that much of the fall migration ma

en overlooked. It would be easy to miss the kingbird's migration if it occurred in just a few days on a very row front. One migration of the sort observed by ungworth (1950) in Iowa would account for a large nber of kingbirds. It is also possible, if improbable, t the eastern kingbird's fall migration largely misses nois. We cannot explain the poor counts of kingbirds he fall, but feel that the counts may not be realistic.

od Habits

Gross & Forbes (1909) roughly summarized the food the eastern kingbird in Illinois as being about 90 cent insects taken on the wing and a modest amount vild fruit. Forbes' (1878, 1881, 1882*a*) studies on the d of the kingbird are sketchy, involving only a few cimens, and being uncharacteristically poor in details. an orchard in Tazewell County with a heavy station of cankerworms, about 25 percent of the food three kingbirds was cankerworms, and nearly 70 cent was beetles, especially scarabs. Stomachs of nine gbird specimens presumably taken in Illinois (dates localities not given) also showed beetles to be minent in the diet, which also included unspecified idoptera and Orthoptera and some Hymenoptera spiders. Nelson (1876-1877) recorded an instance in ch a kingbird captured aquatic insects (unidentified) plunging into a stream somewhat in the fashion of a ed kingfisher (*Megaceryle alcyon*). This method of ing is suggestive of the kingbird's method of bathing plunging kingfisher-like into a pool of water nigmile 1937). The food habits of this species are ously much in need of study.

STERN KINGBIRD (*Tyrannus verticalis*)

(Fig. 6 and 7)

The western kingbird has been extending its range ward in the past century, and now nests regularly as to Illinois as western Iowa and western Missouri. re are about 40 acceptable records of the species in ois, including three definite breeding records.

The western kingbird was first recorded in Ilinois June 924 when a male specimen was found dead on a road ake County (Coale 1924). The 1930's brought more ern kingbird records to Illinois, and the number of rds increased in succeeding decades. In recent des it is quite likely that at least a few western birds have been occurring in Illinois every year, but of them go undetected because of the paucity of ble observers. Western kingbirds have been reported linois virtually every year since 1964 (Dillon 1973; ts 1965, 1966*a*, 1973; Petersen 1966, 1967; Princen , 1970; Kleen & Bush 1972*b*, 1973).

une and July records of the western kingbird in or near northeastern Illinois in 1924, 1935, and 1938 le 1924, Sanborn 1935, Work 1939, Ford 1956) may been indicative of nesting even in those early years. k's (1939) record is particularly suggestive because of ighting of several kingbirds together that may have been a family group. The first certain breeding record of the western kingbird in Ilinois known to us was a nest found one-half mile north of Kilbourne (Mason County), Illinois, and reported to Dr. William Starrett in June, 1965. On June 9, 1965 Frank Bellrose and Jean and Richard Graber visited the site and observed the nest, which was near the top of a signal light post by the C & M railroad tracks in open country. Though the contents of the nest were not seen, one of the birds was observed on the nest. Both birds also demonstrated vociferously when

Fig. 6. — Western kingbird, a species similar in size and shape to the eastern kingbird, but with yellow belly and gray head and back. Also note white outer webs of tail feathers.

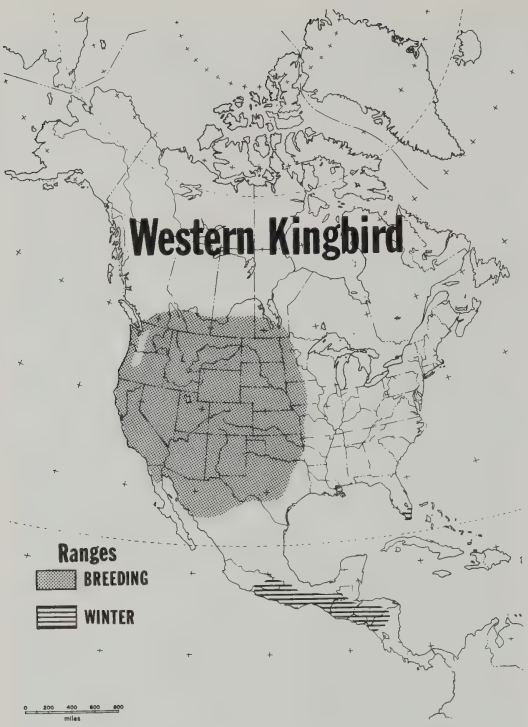


Fig. 7. — General distribution of the western kingbird. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and paucity of suitable habitat.

Fig. 8. — Distribution of the western kingbird in Illinoi

the nest site was approached. The ultimate fate of the nest was not determined.

Another breeding record for the species was obtained only about 4 miles northwest of the Kilbourne nest on August 14, 1967 when Robert W. Guth (personal communication) found a family of western kingbirds 2 miles east of Bath, Illinois. Two young were being fed by both adult birds, and a third young was found dead on the road nearby. A family of western kingbirds with young found near Winnetka, Illinois on August 13, 1970 was almost certainly another Illinois breeding record (Petersen 1970*b*).

Despite these nesting records, we did not include Illinois within the regular North American breeding range of the species (Fig. 7) because of our stated policy (Graber et al. 1970) of drawing the range limits conservatively to indicate areas of regular occurrence of dependable populations.

There are widely scattered records of western kingbirds in the state (Fig. 8), and the relatively large number of records for northeastern Illinois may only reflect the greater number of observers in that area.

The seasonal distribution of Illinois records of the western kingbird is shown in Fig. 9. The earliest spring

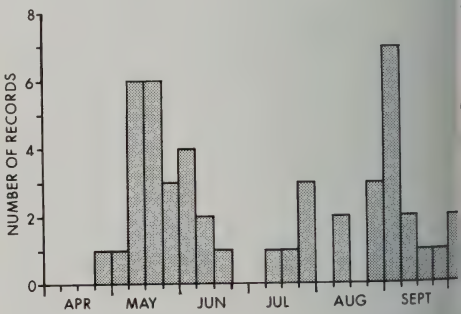


Fig. 9. — Seasonal distribution of the western kingbird re Illinois, showing the weekly distribution of all dated records species (1924-1971).

record was a bird seen near Fairbury, Illinois Ap 1965 (Fawks 1966*a*), and the latest fall record wa bird at Springfield, Illinois October 23, 1948 (M 1949*a*). The peaks of records in the spring and fal 9) seem to indicate that most of the Illinois reco this species represent migrants. The ratio of records to fall records is almost exactly one to one

CISSOR-TAILED FLYCATCHER

(Muscivora forficata)

(Fig. 10)

The scissor-tailed flycatcher can no longer be nsidered of merely accidental occurrence in Illinois. here are at least 21 reports for the species in the state, including 15 since 1965. In addition to these sightings, at least one more has recently been reported from a contiguous area near St. Louis, Missouri (Petersen 1970*a*).

The scissor-tailed flycatcher was first reported in Illinois near Peoria in 1885 by W. E. Loucks (unpublished notes). It was next seen in 1902 by Craigmile

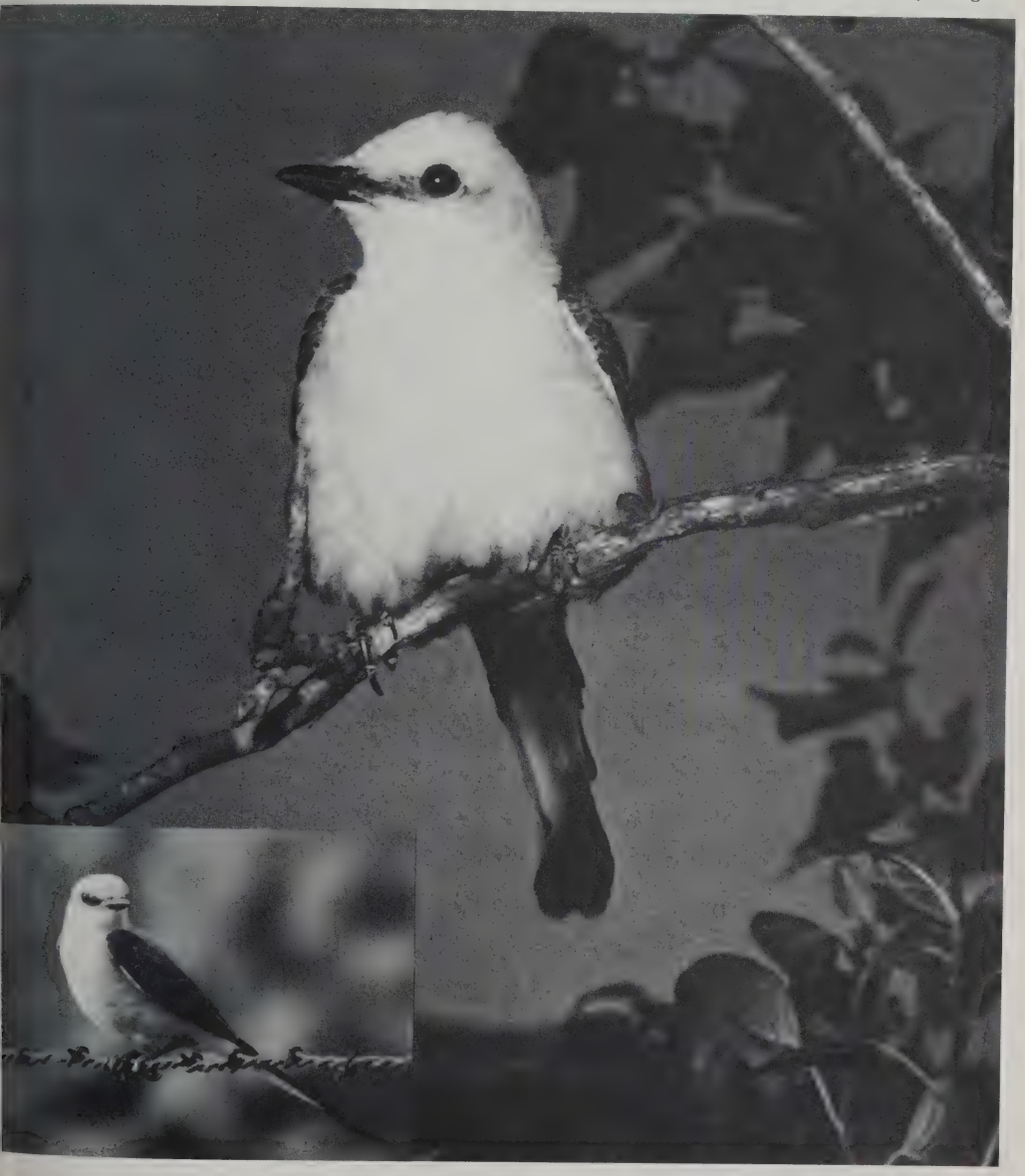


Fig. 10 — Scissor-tailed flycatcher, female. Side view (lower left) shows tail length; males have longer tails.

(1934-1935) in La Grange, Cook County. There were no further records until 1933 when it was again recorded in Cook County by W. Dreuth in Lincoln Park (Clark & Nice 1950). In 1947 a scissor-tail was seen at Wolf Lake, Indiana, within one-fourth mile of the Illinois boundary (Bartel 1947), and in 1954 one was seen south of Chicago (Nolan 1954).

There were only two state records outside of the Cook County area for about a decade preceding the 1960's. One scissor-tailed flycatcher was seen in Jackson County in 1949 (Mayfield 1949*b*) and another was seen in Vermilion County in 1958 (Bursewicz 1958). More recent records are those for Havana (Graber & Graber 1965); Neponset (Fawks 1967*a*); Lacon (Fawks 1967*a*, 1967*b*); American Bottoms between St. Louis and Chester (Hamilton 1969, Fleig 1971); Fultz, with at least five reports from this area, (Anderson 1968); Dixon Springs Agricultural Center (Seets, personal communication 1972); Elmwood (Princen 1968, 1969); Anna (Fawks 1970); Sibley (John Hudson, personal communication 1972); Sparta and Valmeyer (R. Anderson, personal communication 1969, 1972). The preponderance of earlier records for the Cook County area can in part be explained by more thorough coverage of the area by a number of competent observers. However, the overall pattern of Illinois records (Fig. 11) suggests that the species is increasing in occurrence and that the dispe pattern is from southwest to northeast. Illinois typi has a predominant southwest flow of wind that c facilitate movement of this flycatcher from its bree range (or center of distribution) in the southwest to the northeast.

Of the Illinois records, the earliest is April 15 and latest is August 7, with three occurring in April, fo May, three in June, four in July, and one in August. of the June records may be of the same bird, and t are two reports that did not specify dates other "spring" or "summer." The presence of both sex Illinois in summer and the fact that the speci extending its breeding range to the northeast (Grab Graber 1965) appears to presage the nesting of this in the state in the future.

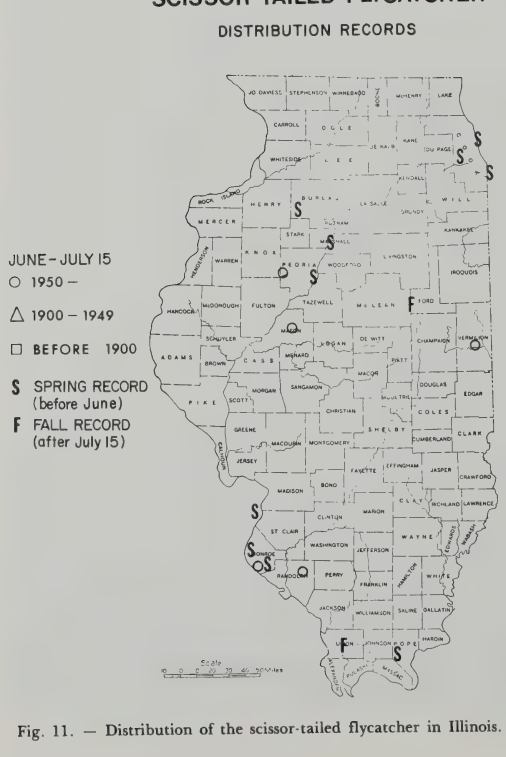


Fig. 11. — Distribution of the scissor-tailed flycatcher in Illinois.

GREAT CRESTED FLYCATCHER

(Myiarchus crinitus)

(Fig. 12 and 13)

Spring Migration

Crested flycatchers are presumed to be night mig on the basis of their occasional occurrence amon species of birds killed at television towers (Stodda Norris 1967). This does not preclude the possibility they also migrate by day.

Crested flycatchers have been seen as early as Ap in southern Illinois, and April 20-21 in the centra northern regions (Fig. 14). The influx of cre increases conspicuously after April 20 in southern Ill April 28 in central Illinois, and May 6 in the north. numbers remain high throughout May and the first in June. As also reported by Widmann (1907), we found crested flycatchers to be very consistent i timing of their spring arrival.

Our spring counts show the migrant populatio cresteds to be consistently higher on the western si the state than on the east (Fig. 14). We cannot ex this difference.

Distribution

The crested flycatcher's breeding range is esse the eastern half of the United States and adj southern Canada (Fig. 13). The Illinois distributi this species is poorly known; though we suspect th species nests in every Illinois county, actual bre records are still lacking for some counties (Fig. 15)

Nesting Habitats and Populations

The great crested flycatcher is essentially a species that frequents the upper canopy of f (Ridgway 1889, Hankinson 1915, Twomey 1945). I in forest interiors as well as forest edge and in u forest as well as bottomland (Gates 1911; Carpenter Kendeigh 1941, 1944; Table 2). Cresteds are also

Fig. 12. — Great crested flycatcher. (Gray throat, yellow belly, and reddish tail are field marks for this species.)

rchards and shrub areas and in residential habitat gway 1887, 1889). Because crested flycatchers nest in ties about 6 inches in diameter, shrub areas and ards may be primarily foraging rather than nesting tats. Our statewide censuses (Graber & Graber 1963) ed no crested flycatchers in orchards in more recent s, though they were present in this habitat in 1907 1909. The statewide censuses also showed surable populations of crested flycatchers in urban ential habitat only in southern Illinois (Table 2), eas the Illinois literature contains a number of rds of cresteds nesting in northern urban areas ny 1945, Work 1936, Wilson 1906, Ford 1915, and others). Ridgway (1887) callled the crested rare "in town," but later (1915) recorded a high density of crested flycatchers (50 per 100 acres) in suburban habitat in southern Illinois. This figure may be exaggerated because of the small acreage covered (Table 2). If, however, Ridgway's 1915 figure was accurate, the implication is that populations of cresteds in residential areas were much higher in Ridgway's time than in recent years.

Barnes (1890), Loucks (1891), and Gates (1911), all of whom worked on or near the Illinois River, believed the species to be most plentiful in bottomland areas, but high breeding populations of crested flycatchers have also been found in upland forest (Table 2). The theses of

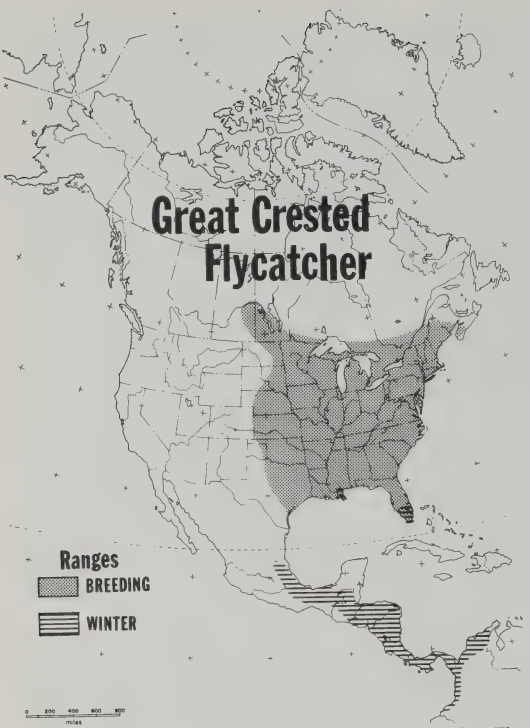


Fig. 13. — General distribution of the great crested flycatcher. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and paucity of suitable habitat.

Holmes (1950) and Weise (1951) provide the best direct comparison of upland versus lowland populations of the crested flycatcher. In Piatt County on and near the Sangamon River, Holmes (1950) found 14 pairs of cresteds per 100 acres in the floodplain forest, and 5 pairs per 100 acres in upland forest, thus supporting the Illinois River data, but Weise (1951) found more pairs (9) in upland than in lowland forest (3 pairs). Cahn & Hyde (1929) considered the crested flycatcher to be a breeding species of cypress swamps, but populations have not been measured in this habitat. Johnston's (1947) data on two forest areas in Champaign County suggest that the crested may be either predominantly a forest edge or a forest interior species, varying from place to place. In their long-term study of Trelease Woods (Champaign County) Kendeigh (1944) and his students found the crested to be primarily a forest interior species.

Older censuses for the crested flycatcher tended to be higher than more recent censuses, implying that the species has declined in Illinois since 1900. Ridgway (1878) considered the crested to be the most abundant flycatcher around Mt. Carmel, but there are no comparative data for recent years. More census data are needed for all areas of the state, but especially so for southern Illinois.

In northeastern Illinois, Swink (1960, 1965) foun that the crested flycatcher showed a definite preferen for oaks, and the few available data on nesting trees al indicate this preference (as the most frequently us species were oaks), and that willows were the seco choice. Other species of trees used by cresteds for nesti were elms (*Ulmus*), apples, sycamore (*Platanus*), a hackberry (*Celtis*). Unidentified dead trees with peel bark were actually used as nest trees as often as willo We have data on only 21 nests, and many more reco are needed to evaluate the importance of differe species.

Allison (1947) found that territories of crest flycatchers were very closely spaced so that all availa area was used by the birds in a Piatt county forest wit high breeding population (25 pairs per 100 acre Published measurements of 26 crested territories central Illinois forests ranged in size from 0.6 to 4.6 ac and averaged, in different years and different plac about 3.1 acres (Fawver 1947*b*) and 1.5 and 3.0 ac (Calef 1953). Twomey's (1945) measurements of territ are apparently based on a different interpretation, as gives figures of about 11 and 14 acres for crest territories in central Illinois.

Nesting Cycle

Little has been recorded (nothing in south counties) on the nesting of the great crested flycatche Illinois. The song most often heard is a loud and rat unmusical "wheeep" or "creeep" with rising inflecti sometimes prolonged with a series of staccato notes at end. In Illinois the song has been heard from the time arrival in April to mid-September. In Piatt Cou Fawver (1947*a*) noted that singing was much reduced July but increased briefly in early August; we h observed the same pattern in southern Illinois.

Homing by the crested flycatcher is indicated by return to Lisle, Illinois on June 13, 1936 of a bird ban there May 30, 1934 (Cooke 1937).

There are no data on the duration of the nest cycle, or any phase of the cycle. The nests, which built in deserted woodpecker holes, or other natura man-made cavities, are composed of grass, cedar b feathers, hair (including fur of small animals), and sn skin (Dickinson 1897, Ridgway 1889, Ford 1932). N heights in natural sites have varied from 34 inches ab ground to about 50 feet, with no obvious domin height range.

In earlier years, crested flycatchers sometimes pla their nests in crevices of buildings (Ridgway 1887, Lo 1895), sites which now are usually occupied by h sparrows (*Passer domesticus*) or starlings (*Stu vulgaris*). Though crested flycatchers have b considered tyrants toward other species of birds (Ridg 1889), and have even driven sparrows, starlings, purple martins (*Progne subis*) away from nest b (Meany 1945), in the long run they are apparently match for the starling (Zeleny 1969). This relation must have had some effect on crested flycat

pulations in urban habitat, but there are no good data show the effect. Red-headed woodpeckers (*Melanerpes ythrocephalus*) have also dominated cresteds in mpetition for a nesting cavity (Ridgway 1915). On the ıer hand, at an established nest in northern Illinois, a ested flycatcher fearlessly attacked red-headed odpeckers, blue jays (*Cyanocitta cristata*), and low-shafted flickers (*Colaptes auratus*) (Pattee 1931). ese few observations on competition for nest sites, etc. olve urban habitat. There are no data on the question competition in natural habitats.

Musselman (1932) noted crested flycatchers taking ssession of nest boxes in central Illinois as early as April and Gault (unpublished notes, 1899) witnessed nest ilding in the north as early as May 18. There is little ormation on the season of egg laying. In central nois, the region for which there is the most ormation, egg laying extends from at least May 17 to y 12 (Fig. 14).

Data on 25 clutches of crested flycatcher eggs from tral and northern Illinois showed the following tribution of clutch size: 7 eggs — 4 percent, 6 eggs — percent, 5 eggs — 36 percent, 4 eggs — 24 percent, l 3 eggs — 4 percent. These data may not be truly resentative of the species, as they are nearly all from old oological collections and old literature. There is one record of cowbird parasitism of the crested flycatcher in Illinois (Blocher 1936).

Nesting success, productivity, causes of nest failure, and, in general, the basic biology of the crested flycatcher in Illinois, are unknown for any population.

Fall Migration

The fall migration of the crested flycatcher is unspectacular to the field observer (Fig. 14). As with a number of other species, the crested population seems to slip away almost unnoticed. In northern and central Illinois we have seen cresteds that were nearly through the postnuptial or postjuvenal molt as early as August 18, and others apparently in fresh plumage on August 26. The fall migration probably begins at least as early as mid-August.

Most observers record the last cresteds of the year in mid- or late September (Fig. 14), with little variation from region to region (Clark & Nice 1950, Dillon 1968, Schafer 1917-1918, Cooke 1888). Our peak fall counts occurred in August and September, and we have no Illinois records of the crested later than October 1. The fall counts are very low, particularly in the south, but they are actually more uniform than the spring counts,

TABLE 2. — Breeding populations of great crested flycatchers in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
rban residential	8	50	1916	Nest	Richland (S)	Cooke 1916, Ridgway 1915
n residential	98	5	1958	Strip	South	Graber & Graber 1963
maple forest	55	7-40 (avg 20)	1927-1972	Nest	Champaign (C)	Kendeigh 1944, Kendeigh & Stubbs 1951
maple forest	64	19	1947	Nest	Champaign (C)	Johnston 1947
le-elm forest	63	22	1950	Nest	McLean (C)	Calef 1953
	63	19	1951		McLean (C)	
nd second growth hardwoods	56	32	1941	Nest	Sangamon (C)	Robertson 1941
	56	21	1942		Sangamon (C)	Robertson 1942*b*
	56	21	1944		Sangamon (C)	Robertson 1944*b*
	46	14	1948		Sangamon (C)	Robertson & Snyder 1948
nd growth hardwoods	15	27	1937-1938	Nest	Rock Island (N)	Fawks 1937, 1938
ed bottomland woods	93	24	1955	Nest	Macon (C)	Chaniot & Kirby 1955
n floodplain forest	77	12	1948	Nest	Sangamon (C)	Snyder et al. 1948
dplain forest	50	20	1946	Nest	Piatt (C)	Fawver 1947*b*
nd oak-hickory forest	24	4	1967	Nest	Hancock (C)	Franks & Martin 1967
o oak forest interior	40	4	1968	Nest	Mason (C)	Johnson 1970
odified woodland	27	15	1937	Nest	Lake (N)	Beecher 1942
fied woodland (human housing)	28	7	1937	Nest	Lake (N)	Beecher 1942
t (all types including edge)	98	3	1958	Strip	North	Graber & Graber 1963
	97	8	1957		Central	
	117	5	1958		Central	
	20	20	1907		South	
	40	28	1909		South	
	174	5	1957		South	
	166	1	1958		South	
shrub	21	14	1966	Nest	Vermilion (C)	Karr 1968
o areas	17	11	1907	Strip	South	Graber & Graber 1963
	39	2	1909		South	
	67	3	1957		South	
ard	19	5	1907	Strip	South	Graber & Graber 1963
	26	4	1909		South	

[a] All figures were converted to read birds per 100 acres (territorial males or nests X 2).

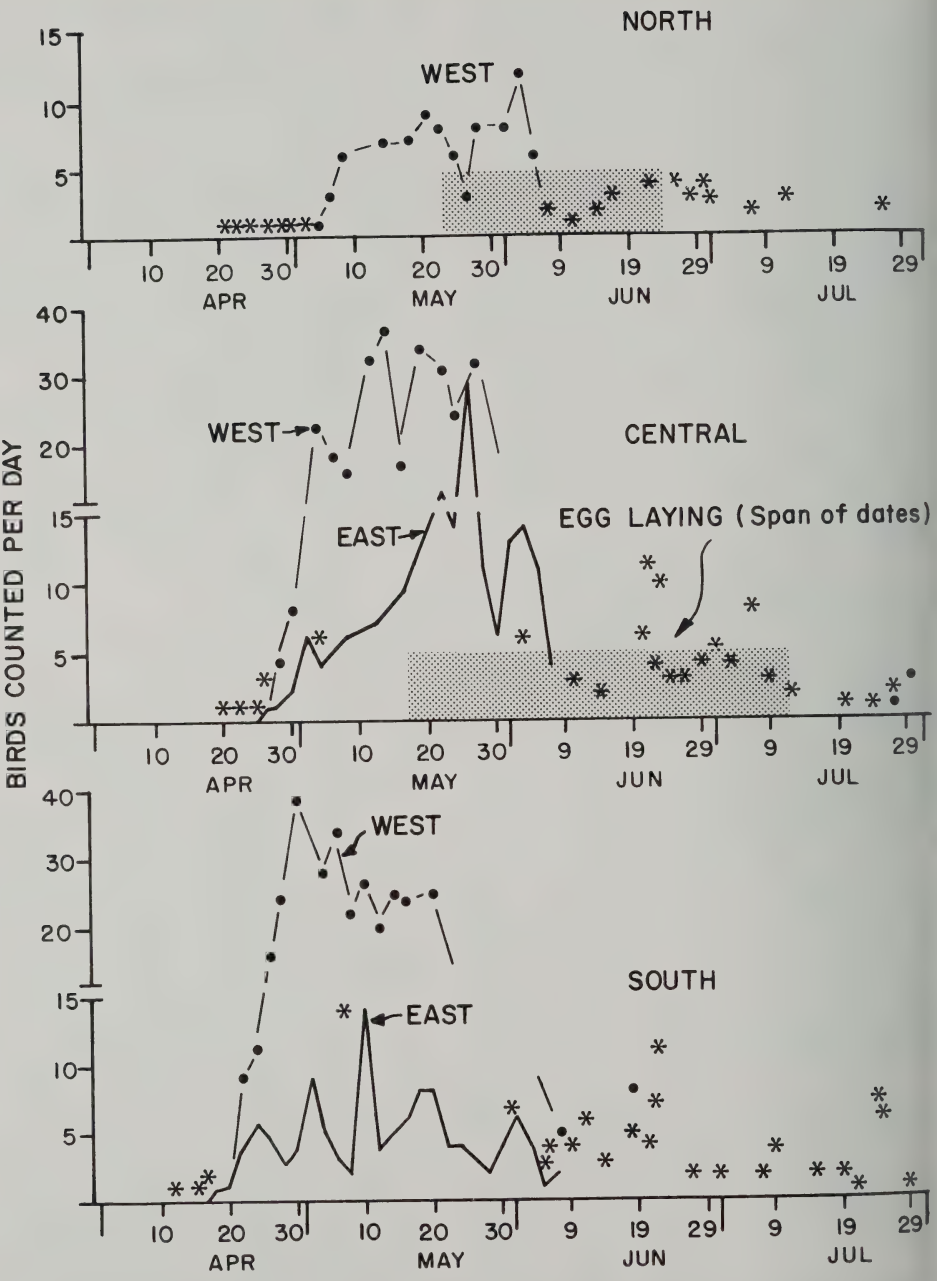
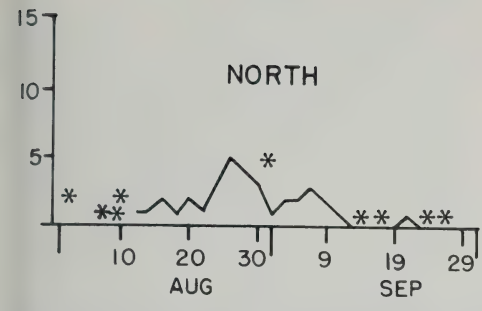
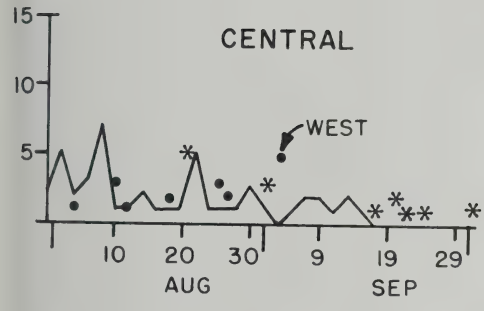
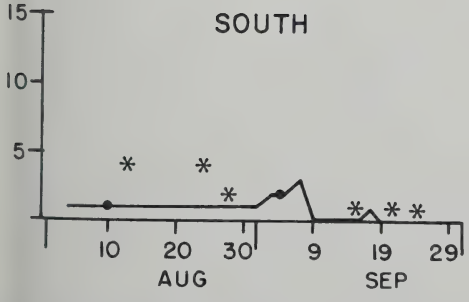


Fig. 14. — Egg-laying and migration seasons of the great crested flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other years or by observers. Shaded areas show span of dates during which egg layi been recorded. The species nests commonly in southern Illinois, b







have not been recorded. Dot symbols represent counts made on
estern side of the state; lines without dots represent the eastern

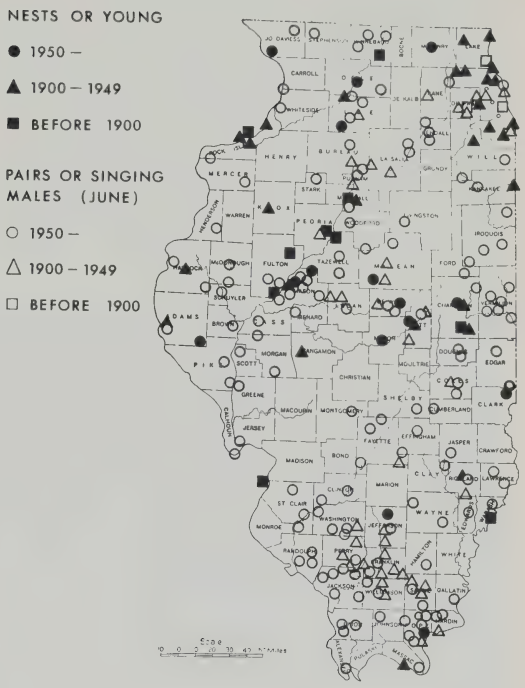


Fig. 15. — Breeding records for the great crested flycatcher in Illinois. Singing male records cover the period June 1 to early July.

and the spring-to-fall ratios show a marked progression from northern Illinois (3.8 cresteds in the spring to 1.0 in the fall) to central (8.1 in the spring to 1.0 in the fall) to south (33.9 in the spring to 1.0 in the fall). The fall migration of the crested flycatcher goes largely unseen.

Crested flycatchers are rare victims of the television towers. We know of only five crested specimens among the many thousands of night migrants killed at central Illinois towers. These cresteds were killed between September 2 and 21. There is an apparent geographic pattern to the crested kills, for all of the specimens have been found at towers west of Champaign County, despite the fact that thousands of birds of other species have been picked up at towers in Champaign and Vermilion counties. We cannot explain this distribution.

Food Habits

The stomach contents of five crested flyctacher specimens constitute virtually all of the available data on the species' food habits in Illinois (Rice 1946, Twomey 1945). Obviously, much more study is needed. The food was nearly all insects, with unspecified Diptera, Hemiptera, Hymenoptera, and Lepidoptera making up most of the sample. Pattee (1931) also saw that young cresteds in a nest were being fed insects, including a large butterfly.

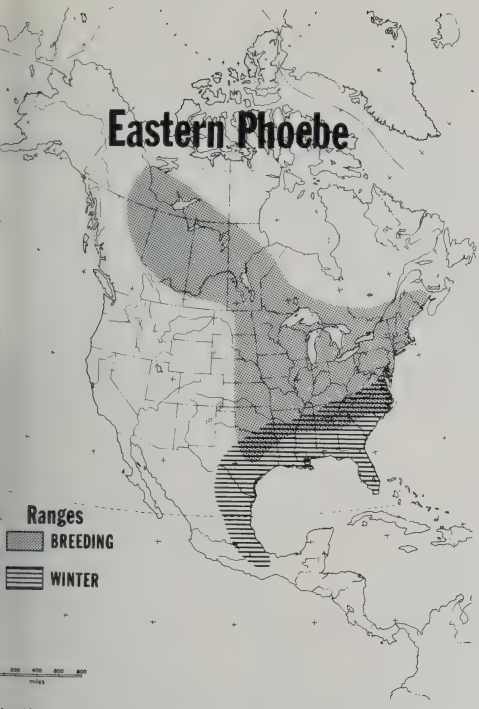
EASTERN PHOEBE (*Sayornis phoebe*)
(Fig. 16 and 17)

Spring Migration

There are no data from which to judge whether the migration of the phoebe is nocturnal, diurnal, or both. Phoebes occur in Illinois in winter, but the winter population is almost negligible, and the possibility of confusing a winter bird with early spring migrants seems remote. Spring arrivals for the eastern phoebe have been recorded as early as February 1 and 15 in southern and central Illinois, and February 26 in the north (Ridgway 1915, George 1968, Musselman 1921*b*, Ford et al. 1934). We observed more conspicuous influxes of phoebes on March 6 in the south, and around March 20 in t central and northern regions (Fig. 18).

Compared with the migration of many other speci the phoebe's migration is rather inconspicuous. Observ often detect the first few phoebes to return in spring, l in general no large numbers of transient phoebes seen. It is exceptional to see even as many as 10 per (Fig. 18). The species tends to be solitary, and we ha never seen what could be called a real flock of phoebes the spring. Our counts show great daily variation, l there is no consistent pattern in the spring counts fr region to region. The central Illinois data show p numbers in mid- and late April (Fig. 18), but with m years of observation Ekblaw & Ekblaw (1916) found p

Fig. 16. — Eastern phoebe in fresh fall plumage. This species is without bright colors. Photo taken at Urbana in Champaign County.



ig. 17. — General distribution of the eastern phoebe. The outlined e may include large sections in which populations of species are or even absent because of the nature of the terrain and paucity of ble habitat.

nbers in east-central Illinois between March 22 and In northern Illinois there is evidence of a peak in the ebe migration in late March (Brownell 1916, Rogers 4), but Swink [1965] called April the month of atest concentration of phoebes. In southern Illinois highest spring counts of phoebes came in mid-March early and late April.

ribution

The eastern phoebe has an extensive breeding range astern and central North America, and a winter ge in southern United States and eastern Mexico (Fig. In Illinois the phoebe probably nests in every county, igh there are a number of counties in which breeding t still be verified (Fig. 19). In addition to the records ted on the map, there are June records for recent s in Jersey and Madison counties (personal munication from Dick Anderson, no specific lities given).

ting Habitats and Populations

Brewer (in Ridgway 1889) felt that phoebes were acted to two kinds of places — the vicinity of llings and the vicinity of water. An important factor omitted from his statement is the need for some kind of woody cover, something more than just a hedgerow. We have never found nesting phoebes more than a few yards from substantial woody cover, even where there were excellent nesting sites and good streams. This means that there are sizable (and expanding) tracts of agricultural land without nesting phoebes.

Gates (1911) considered the species to be common in bottomland forest. Robertson (1941, 1942*a*, 1944*a*) found one pair of phoebes nesting each year on about 64 acres of "swampy prairie" in Sangamon County. This "prairie" habitat did, however, contain some woody cover. Fawks (1937) found one pair in 15 acres of upland woods near Rock Island. In Piatt County Fawver (1947*b*) found two pairs of phoebes per 100 acres in floodplain forest, and determined the size of one territory to be 0.7 acre.

Because of the phoebe's requirement of a shelf or wall of some sort for nest placement, phoebe territories are often not contiguous. Usually there is but one pair (if any) nesting at a bridge or a farmyard, for example, and the spacing of phoebes may thus often be more dependent upon the spacing of bridges than upon the size of the territory of the bird. This spacing is not true however of rocky bluff areas, where numerous nest sites may be available through miles of continuous forest habitat. In such situations phoebes may be closely spaced. At One Horse Gap in Pope County, where there are extensive rock bluffs in forest areas (Fig. 20), we found six contemporaneous nests in an area of about 30 acres. The two most closely spaced of these nests were about 270 feet apart. This area had a particularly dense population of phoebes. Other rock areas we visited in southern Illinois had only one or two pairs in 30 acres. Some large areas (100 acres or more) of suitable-looking habitat were without phoebes. Phoebe habitat has never been precisely defined, and we cannot account for the variation in populations. We suspect that there may be a relationship between the humidity in rock canyons and phoebe populations, but this suspicion needs testing.

Away from rock bluff areas, the usual nesting places are bridges, culverts, and buildings. Phoebes nest both on and inside buildings. They appear to choose nest sites offering some measure of overhead shelter, and nests on rock walls are nearly always placed under an overhang (Fig. 21). As the phoebe's nest contains a large amount of mud, protection from rain may be essential to keep the nest from washing away. Some naturalists feared that phoebes might suffer a great loss of nest sites as bridges with iron I-beam girders gave way to cement culverts (Ford 1956), but phoebes adapted to the cement structures successfully (Blocher 1933).

Phoebe nests in natural rock settings vary in height from about 2½ feet to more than 20 feet, but are generally under 6 feet. Nests on buildings are usually about 7-9 feet high, the height of porch braces. The heights of bridge and culvert nests are similarly incidental to the birds' choosing.

Swink (1960) observed that hawthorn (*Crataegus*),

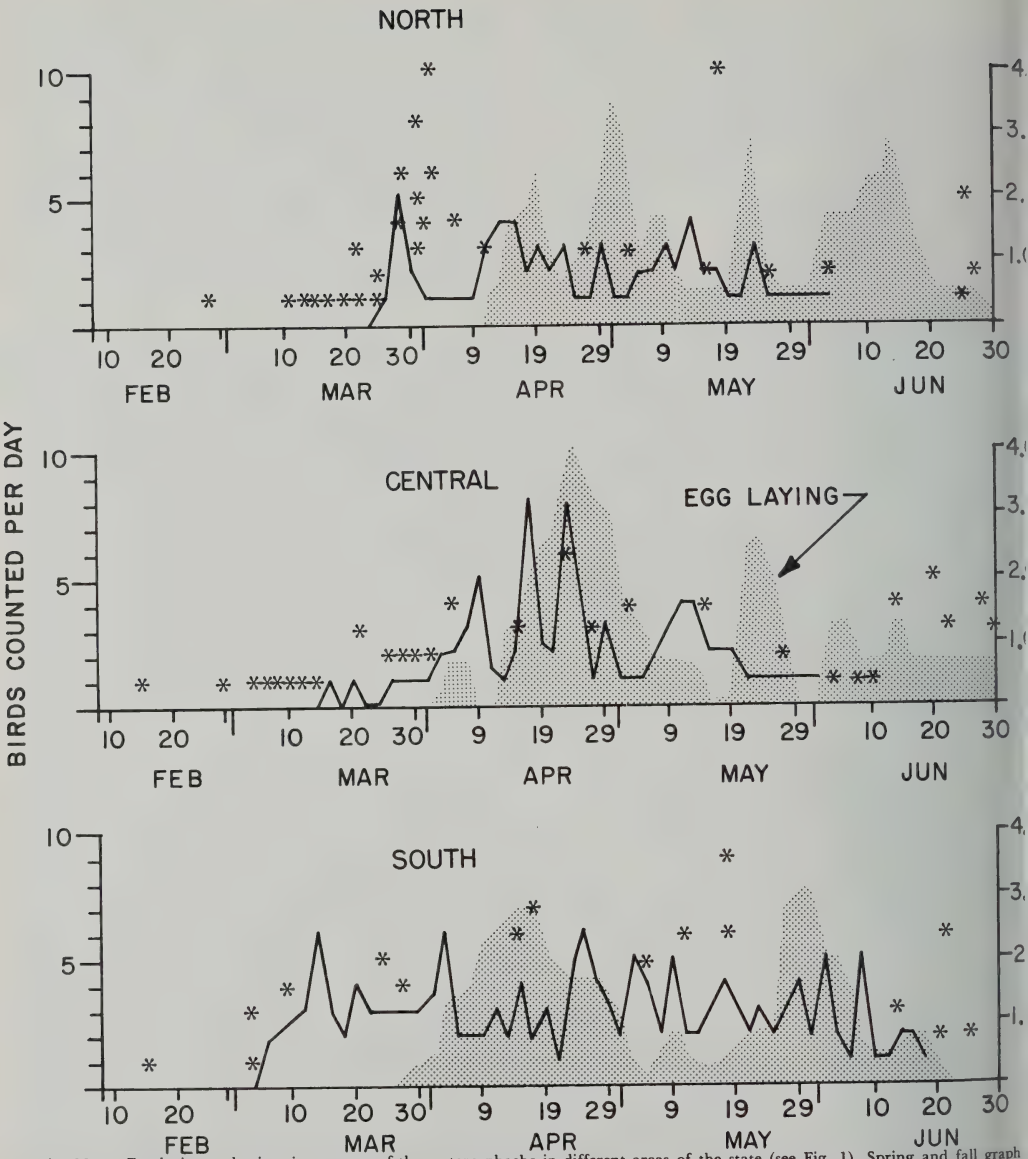
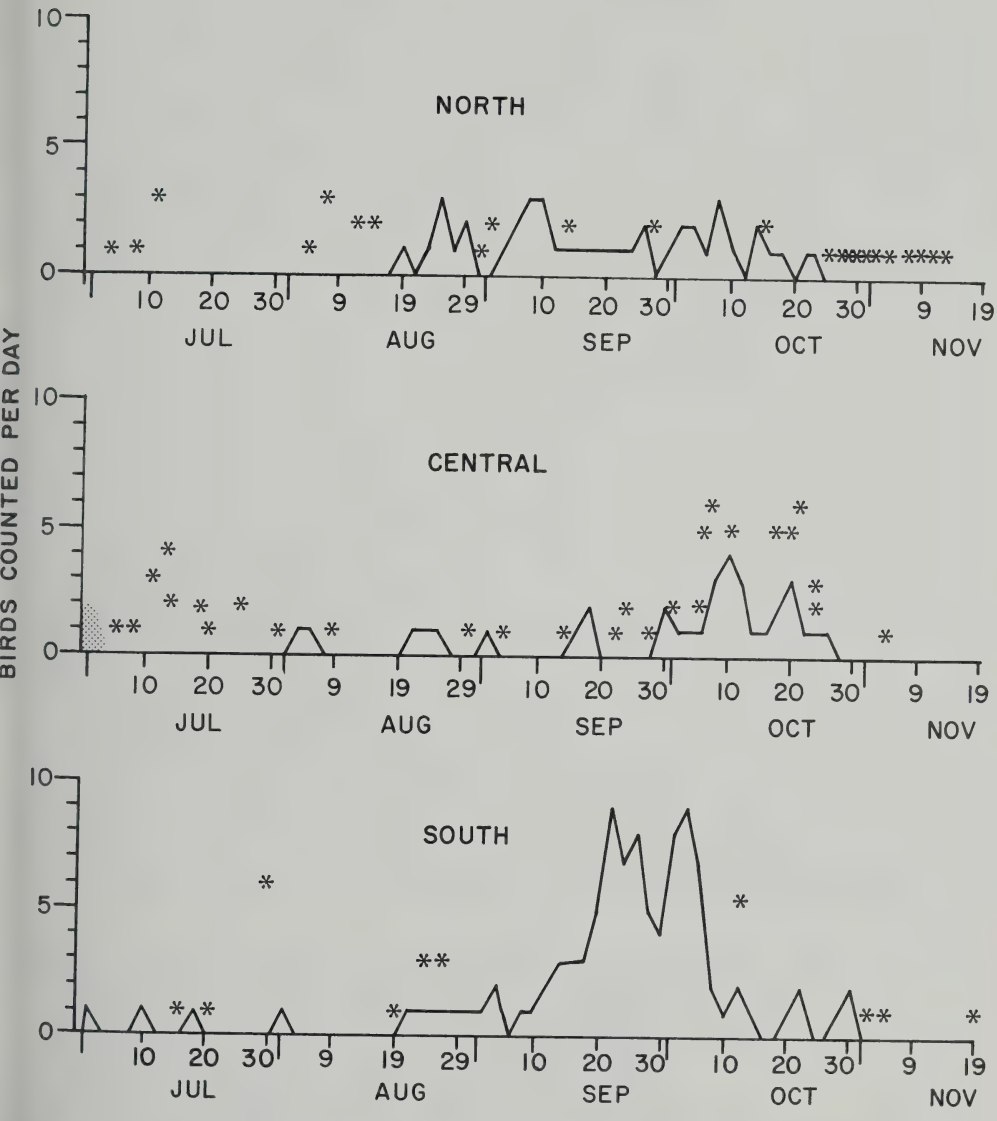


Fig. 18. — Egg-laying and migration seasons of the eastern phoebe in different areas of the state (see Fig. 1). Spring and fall graph (1967-1970) show highest daily counts of each 2 days (left scale). Asterisk symbols represent counts made in other years or by other observers. Sh areas show the percent of eggs laid on a given date (right scale).

willow, black cherry (*Prunus serotina*), and apple were the most frequently used perching sites of phoebes in northeastern Illinois.

Phoebes appear to be very tolerant of humans, often nesting on the porches of rural homes in forested areas. They also nest in towns and cities, but despite availability of numerous nesting sites in cities, pho populations appear to be consistently very low in ur areas. Barnes (1912) believed that the phoebe popula was declining, and attributed the decline, at least in p



ouse sparrows driving phoebes away from nest sites on dings. If true, this competition with sparrows could n explanation for low phoebe populations in urban lential habitat. In recent years we have also seen the by house sparrows of phoebe nests under bridges.

f the phoebe population of Illinois is showing a trend ther direction, decreasing or increasing, present data ot adequate to show the trend. Through the years a number of authors have reported the phoebe population to be declining in Illinois, and there appear to be periodic population "crashes" in this species (Mayfield 1951, Nolan 1958) similar to those seen in the bluebird (*Sialia sialis*) population (Graber et al. 1971). Hodges (1953) estimated that there was a 70-percent decline of the phoebe population in 1953 in the Rock Island-Davenport area. James' (1960, 1961) analysis of population data

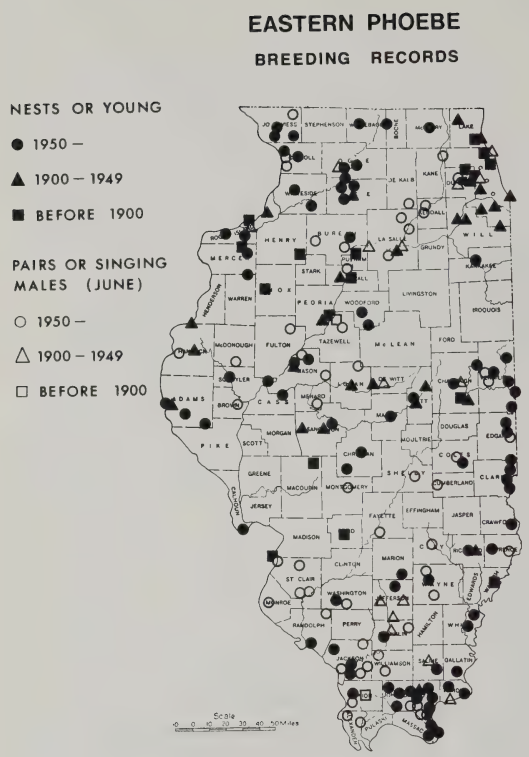


Fig. 19. — Breeding records for the eastern phoebe in Illinois. Singing male records cover the period June 1 to early July.

from the wintering grounds of the phoebe indicated that the phoebe population crashes represented actual mortality related to severe weather on the wintering grounds. Schafer (1921) recorded weather-induced mortality of phoebes in April. The phoebe population that crashed badly in parts of Illinois in 1957 appeared to be completely recovered by 1960 (T. E. Musselman, personal communication). Such crashes are a different phenomenon perhaps than any long-term changes that may be occurring. We need annual surveys of several nesting populations at locations throughout the state to determine if the phoebe population is increasing or decreasing over the years.

Nesting Cycle

Phoebes are already in song when they arrive in spring, but whether this is true of local breeding birds only, or also of transients passing through, we do not know. The song, phonetically, is slightly different than the sound of the name, and at different times sounds like "fee-burt" or "fee-bree" with emphasis on the first syllable. Phoebes also utter a rather soft but emphatic "chip," apparently an alarm note heard often near the nest, and a chattering call, the function of which we not know. Silloway (unpublished notes, 1923) observed kind of flight song performance by this species on Ap 12, 1923 in Peoria.

There are no published band returns to indicate t incidence of homing by phoebes to nest sites in Illino The same nest sites are often used over and over throu the years, but such use cannot necessarily be interpret as homing by the same birds either in different years, for different nestings within a year. Farwell (19 recorded phoebes nesting on her house in northeaste Illinois at least 15 years in succession. The same sites rock overhangs are also re-used year after year (Bonn 1917). One possible implication of these observations that good phoebe nesting sites are in short supply.

We have found completed new nests as early as Mar 23 in southern Illinois, and nest-building probably beg there at least as early as March 15. In central Illinois t earliest completed nest known to us was March 27. In t north, nest construction by phoebes must not begin mu before the first of April, but we have no firm observatio on this. There are no accurate measurements of the ti required for nest construction of early nests. We ha observed nests, both from an early stage of constructi and virtually completed, to go 5-11 days before the fi egg was laid. Several seemingly completed nests in regions of the state remained empty 7-9 days before first egg was laid. Construction of complete new ne later in the season (second nestings) was faster, shortest time being 7 days before the first egg was l (Fig. 22). One nest that was merely refurbished empty only 4 days before a new clutch was started, more often the interval was 6-13 days (Fig. 22).

Phoebe nests are durable and the structures often from one year to the next, but we know of no instanc which a year-old nest was used again without be essentially rebuilt. The nests are composed of mud, gr bark fiber, and moss, lined with hair, wool, and pl fibers (Silloway 1906; Sanborn & Goelitz 1915; Willi Loucks, unpublished notes). The structure is distinc and attractive (Fig. 23) with its covering of green m Phoebes occasionally use old nests of barn swall (*Hirundo rustica*), but add at least a little moss to structure (Fig. 24). The phoebe does not appear compete directly with the swallow, but merely uses abandoned swallow nest.

Egg laying begins as early as March 28 in south Illinois, April 4 in the central region, and April 12 in north (Fig. 18). There are at least two conspicuous pe in egg laying in all regions of the state, and implication is that the phoebe attempts to raise at l two broods. The two major peaks in egg production oc about mid-April and late May in southern Illinois, April and late May in central Illinois, and early May early June in northern Illinois (Fig. 18). The egg-lay curves include data from re-nestings following failure, which tends to skew the main peaks and prod secondary peaks (Fig. 18).

Most phoebe nests in Illinois receive 5-egg clutc

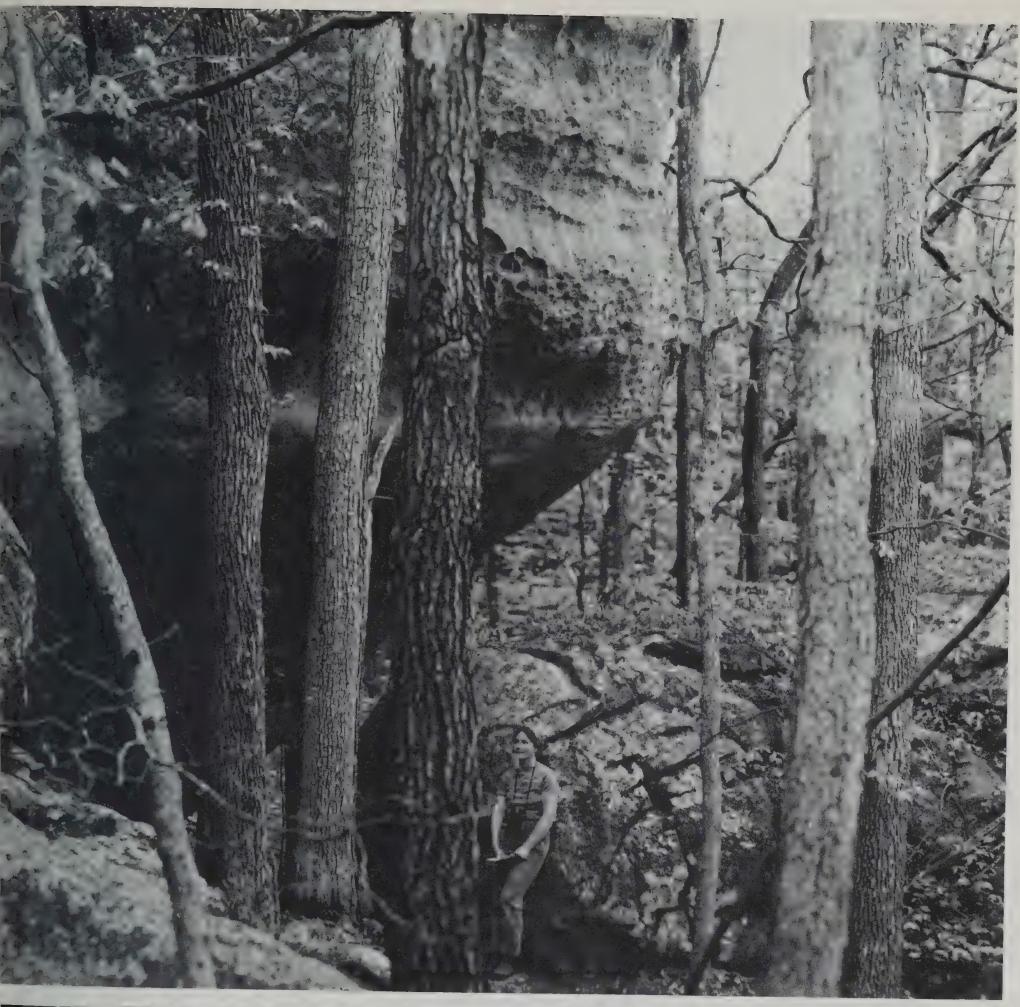


Fig. 20. — (Above.) Natural habitat of the eastern phoebe, cliffs with overhang in forest. Photo taken at One Horse Gap in Pope County.

Fig. 21. — (Left.) Eastern phoebe nest on wall (near observer's hand) of cliff shown in Fig. 20.

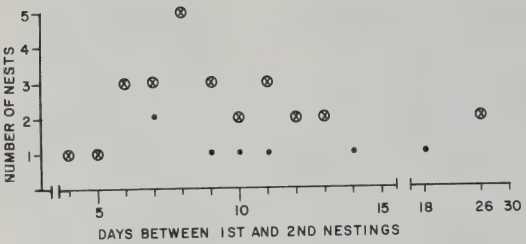


Fig. 22. — Number of days between the end of the first nesting and the beginning of the second nesting of eastern phoebes. Circled symbols represent re-use of same nest structure used in first nesting. Dot symbols represent new nests constructed near site of first nesting.

(Table 3), even in second nestings. At a bridge in Cla County, where at least three phoebes attempted occupy the same territory, two contemporaneous nes were built, one of which received 7 eggs and ultimate fledged one young. Two females probably contributed the clutch. Clutches of more than 6 eggs are abnorm and even 6-egg clutches are uncommon. Though we ha found many nests with 2 and even only 1 egg, all we cases in which predation may have occurred. Phoebe eg are usually immaculate white, but some clutches a faintly speckled with reddish brown.

The phoebe is a common victim of cowbird parasitis in most of Illinois. Phoebe nests for which we ha relatively complete histories showed an incidence about 14 percent in the north, where Blocher (193

Fig. 23. — Typical eastern phoebe nest in rock niche.

Fig. 24. — Eastern phoebe at nest built in old barn swallow nest built on an electrical insulator.

TABLE 3. — Clutch sizes of eastern phoebes in different regions of Illinois.

	Months	Number of Nests	Average Clutch	Percent of Nests by Clutch Size			
				6 Eggs	5 Eggs	4 Eggs	3 Eggs
	April-May 15	14	4.9	7	71	21	0
	May 16-June	20	4.7	0	70	30	0
	April-May 15	17	5.0	6	88	6	0
	May 16-June	13	4.7	0	77	15	8
	March-May 15	31	5.0	13	74	13	0
	May 16-June	32	4.5	0	53	47	0

reported an incidence of 50 percent. Our data exclude nests that had phoebe eggs perforated (probably by cowbirds) but in which no cowbird eggs were laid. Our nest records showed a higher rate of parasitism in central Illinois (29 percent) than our nests in the north, but the highest rate (33 percent) occurred in the northern counties of the southern region (north of Franklin County). On the other hand, in extreme southern Illinois south of Saline County where we studied 73 nests we did not find one parasitized nest.

Of the 10 parasitized nests for which we had complete data, only 1 produced a phoebe (one phoebe plus one cowbird), 3 produced only cowbirds, and 6 failed completely, though not necessarily due to the parasitism.

Incubation periods that we determined at several nests in different parts of the state were 15-17 days, usually 16, and nestling life was also 15-17 days. Nestling phoebes tend to remain in the nest as long as possible and often cling to the edge of the nest until their combined growth appears to exceed the capacity of the nest to hold them. In a nest with only two young the nestling stage was prolonged to at least 20 days. Upon fledging, phoebes usually fly well, but not with the competence of fledging swallows. A good first flight for the phoebe is probably important, because many phoebe nests are over water. At one nest we observed that at least some of the fledglings returned to the nest the first night.

The nesting cycle for a first nesting, from onset of nest-building to fledging of young for a nest with five eggs, would be about 45 days: 9 days for nest building including the delay before the first egg is laid, 4 days for egg laying, 16 days for incubation beginning with the fourth egg, and 16 days of nestling life. Nest building can be at least as short as 7 days, reducing the cycle to 43 days. In renesting the time could be reduced by 5 days, as refurbishing a nest can be done in 4 days or less (Fig. 22). Reducing the clutch size also reduces the cycle time by 1 day per egg. Thus, the cycle could be only 38 days for a nest with 3 eggs.

Even with such a long nesting cycle the possibility exists that a female could produce three broods in a year, as the egg-laying season is also long (Fig. 18). We suspect, however, that three broods would be exceptional. Estimating from the early laying dates (Fig. 18), the first fledglings could be expected about May 1 in southern Illinois, where we have seen grown young independent of their parents as early as May 26. At the other extreme, in central Illinois where the last eggs were laid July 2, nests with young could theoretically still be found as late as the first week in August. We have never found active nests later than July 18. We rarely observed postfledged young.

Nesting success of phoebes was lower than we had expected in view of their protected nest sites (Table 4). In the northern and central regions, and in the northern counties of the south, success (30-43 percent of eggs fledged) in our samples of nests and eggs tended toward inverse correlation ($r = -.763$) with cowbird parasitism. Significantly, most of these nests failed during the egg-laying or early incubation phases of the nesting cyc which is also indicative of cowbird interference. Becau none of the nests in extreme southern Illinois we parasitized by cowbirds, we expected higher success these nests, but they were even less successful than nests more northern populations (Table 4). The unsuccess nests in extreme southern Illinois failed about equa during the incubation stage and the nestling stage. T least successful nests and eggs (17 percent of eggs fledg were the second nestings in extreme southern Illinois.

We have too little data to quantify the causes of n failures. The cowbird was probably a significant factor all but the extreme southern counties (see abov Hatchability of eggs in unmolested, carefully check nests appeared to decline with latitude. In the nor hatchability was an amazing 97 percent, but in central region it was only 83 percent. Eggs in early ne in extreme southern Illinois showed a hatchability of percent, but only 71 percent of the eggs in second ne hatched. Flooding of nests because of rising streams wa serious problem, especially in the south. Falling ne were also probably a significant mortality factor, l such incidences cannot definitely be differentiated fr nest dislodgement by predators, human vandals, livestock. The effect is the same in any case.

Nests in extreme southern Illinois appear to be mu more subject to predation than more northern nests. the south we saw evidence of nest predation from birds both eggs and young, and in at least one case predator was probably a blue jay. In central Illir Musselman (1933) found a house wren (*Troglody aedon*) removing 4-day-old phoebes from their nest, a in the north we saw one phoebe nest taken over by ho wrens, but do not know whether there was real predat in this case. Snakes — in one case a black rat sn (*Elaphe obsoleta*) (Ridgway 1914) — have also b recorded as predators on phoebe nests (Bowie Hann personal communication). Death of nestlings from he infestations of lice or mites occurred in at least two n in the south (see also Hunter 1935), and the death of brood of phoebes appeared to coincide with roads spraying of herbicides near the nest.

Fall Migration

As do many other species, phoebes bec particularly inconspicuous in late summer. One nes population of phoebes that we studied at a rock bluff a in Pope County disappeared entirely by July 8, tho the last young had fledged only 9 days earlier. population had surely not migrated, but had prob either dispersed or moved its center of activity. movement may be fairly typical, as most phoebes app to quit their nesting areas in July.

We have seen independent young phoebes as earl May 26 and newly fledged young on July 18 in south Illinois, but there are no data to show when any of t young birds or their parents begin fall migration, or w

TABLE 4. — Fledging success of eastern phoebes in Illinois.

Region	Years	Months	Number of Nests	Percent Fledged		Percent of Nests with Cowbird Eggs
				Nests	Eggs	
rthwest	1968	April-June	22	57	43	14
ntral	1969, 1972	April-June	21	57	41	29
uth:						
rth of Franklin Co.	1972	April-June	16	47	30	33
uth of Franklin Co.	1967, 1970-1972	April-June	60	36	29	0
		April-May 15	30	45	38	0
		May 15-June	30	23	17	0

y do until they start migration. The time of day when gration occurs is also unknown. We have not found oebes among the thousands of night migrants killed at nois television towers.

We have only scant data on the molt. We have seen ıng in the post-juvenal molt on August 5 in central nois, and a "flock" of six phoebes in fresh plumage on y 29 in southern Illinois.

The onset of the fall migration in this species will obably not be known certainly without careful studies ng banded birds, or telemetry. Swink's (1960) counts phoebes in northeastern Illinois, and ours for the rthwest and other regions of the state (Fig. 18) show ıt September-October is a period of notable activity for oebes. Our counts, though highly variable from region region, suggest that the migration may begin in late gust and that it is largely over by the end of October, h highest peaks occurring in September and October g. 18). Phoebe records as late as November 10 and 13 northern Illinois (Cooke 1908*b*, Lyon 1933), vember 4 for central Illinois (Graber 1962), and vember 19 for southern Illinois (Graber, unpublished) ıld be interpreted either as late fall migration or early lux of winter birds.

Neither Swink's (1960) counts nor ours for spring and account for any productivity. The ratio for all regions 04 to 1.00) of spring (March-April) to fall ptember-October) counts actually shows more birds in spring. The ratio was 1.2 phoebes in the spring to 1.0 he fall in northern Illinois, and 1.8 to 1.0 in central nois. Only in the south where the largest numbers of oebes were seen was the fall count higher (1.0 in the ing to 1.3 in the fall).

nter Records

The eastern phoebe has been reported in the winter least 15 records) in all three regions of the state (Fig. . Nearly all of these records fall between December 18 l January 1, and most of them are from recent (since 0) Christmas censuses. There are almost as many orts from northern Illinois as from the southern ion, probably reflecting the distribution of observers ıer than of birds. In recent years especially, phoebes e been reported in the winter in the Christmas counts

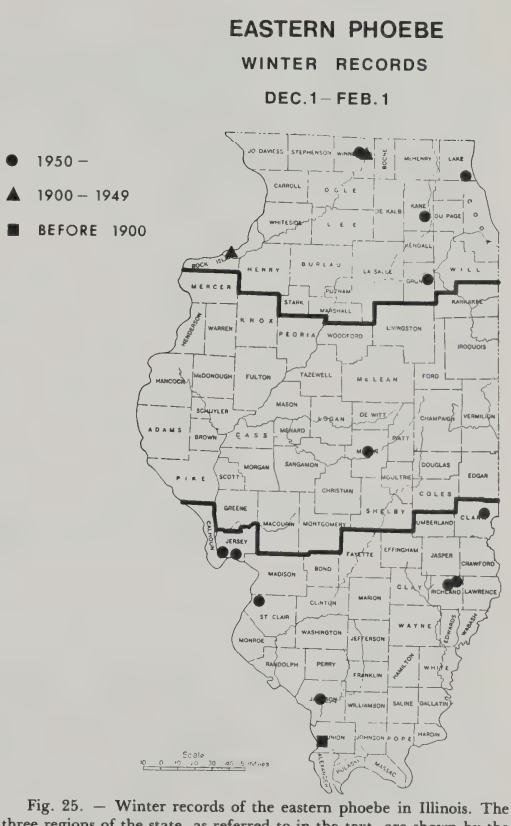


Fig. 25. — Winter records of the eastern phoebe in Illinois. The three regions of the state, as referred to in the text, are shown by the heavy lines.

of many northern states, including Vermont in 1965 and 1972 and Maine in 1967. It is still questionable whether phoebes actually winter through and survive in these northern areas, including Illinois.

The earliest mention of the phoebe in winter is that of Cooke (1885) for southern Illinois. Recent checklists of birds indicate that the phoebe is generally absent from southern Illinois from mid-December to mid-February

(George 1968, Kleen & Bush 1971*c*), and this corresponds to our observations. Though Ridgway (1915) suggested that the phoebe actually wintered near Olney, the winter phoebes in Illinois may actually be late stragglers of the fall migration and/or early spring migrants. The question still remains to be settled. The literature contains nothing on the habitat phoebes occupy in the winter, but Richard Thom (personal communication) observed one on December 27, 1972 near Stringtown in flooded bottomland grown up to maple (*Acer*) saplings.

Food Habits

The food of Illinois phoebes is essentially unknown. Both Forbes (1878) and Gault (unpublished notes, 1889) noted the dominant item in a few phoebe stomachs to be beetles (unspecified). In central Illinois in October we have seen phoebes eating pokeberries, and the bird in Fig. 24 is feeding a skipper (Hesperiidae) to its young.

Among the most interesting observations of phoebe food habits were those of Dr. Lewy (Jung 1926) and Binford (1957), both of whom observed the same behavior at the same place but 30 years apart. They saw phoebes catching and eating small fish at a lagoon in Jackson Park, Chicago. From Binford's account, the birds perched about 2 feet above the surface and peered into the water. The fish were massed in a large school and when they came to within 2-3 inches of the surface, a phoebe would dive and catch a fish in its bill. Only the bird's head and upper breast touched the water. Two phoebes caught seven fish (1½-2½ inches long) in 20 minutes.

This method of fishing is very suggestive of the flycatchers' method of bathing, diving at the water from a perch above and hitting the surface with the breast and head.

SAY'S PHOEBE (*Sayornis saya*)

There are two or possibly three records for Say's phoebe in the state. According to Nelson (1876-1877) two specimens were collected by Kennicott at West Northfield in Cook County prior to 1876 and were listed in the catalog of birds at the museum of Northwestern University at Evanston. The specimens were not in the collection, however, when Nelson examined it. The only other record for the species is a sighting December 30, 1966 at Joppa in Massac County by Bob Montgomery and Larry Hood (Petersen 1967). This species has been reported from Porter County, Indiana (Pitelka 1938) and from the St. Louis, Missouri area (Comfort 1953). There are a number of fall-winter records (see Audubon Field Notes or American Birds) for northeastern states (particularly New York, New Jersey, and Massachusetts) and a few for southeastern states (Louisiana, Alabama, Florida, and North Carolina). A western species, the nearest nesting Say's phoebes are in extreme northwestern Iowa (Bryant & Youngworth 1962).

YELLOW-BELLIED FLYCATCHER

(*Empidonax flaviventris*)

(Fig. 26)

(For an illustration representing this flycather, see Fig. 37

Spring Migration

The yellow-bellied flycatcher is known to be nocturnal migrant; though diurnal migration is unknow in the species, it would be a difficult thing to prove, p or con.

As they return from their wintering grounds in Centr America, the first yellow-bellied flycatchers may rea Illinois by the end of April (Walter & Walter 1904), b most of them come later (Fig. 27). The species is usual not detected before May 6-8 in the south (Cooke 1908*a* May 14 in central Illinois (Smith 1930), and May 15-17 the north (Ford et al. 1934, Clark & Nice 1950). W observed peak numbers of yellow-bellies on May 12 southern Illinois, May 22 in the central region, and M 28 in the north (Fig. 27). Petersen (1965) found that t yellow-bellied flycatcher outnumbered other Empidon at Davenport, Iowa, where 41 were captured with a m net between May 25 and 31, 1968 (Petersen 1968*b*

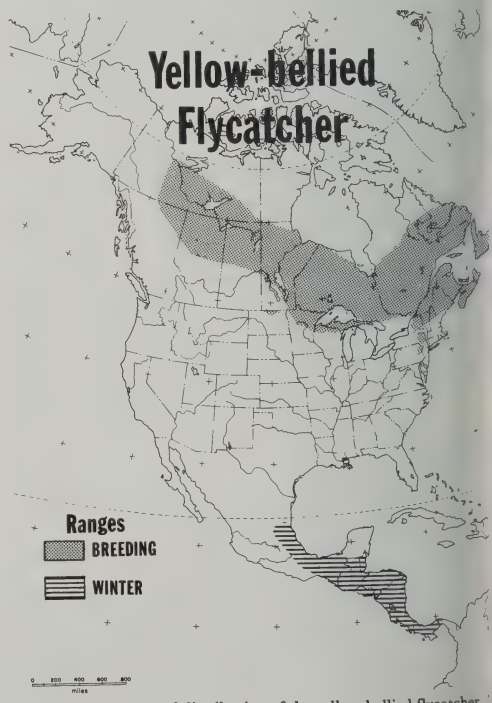
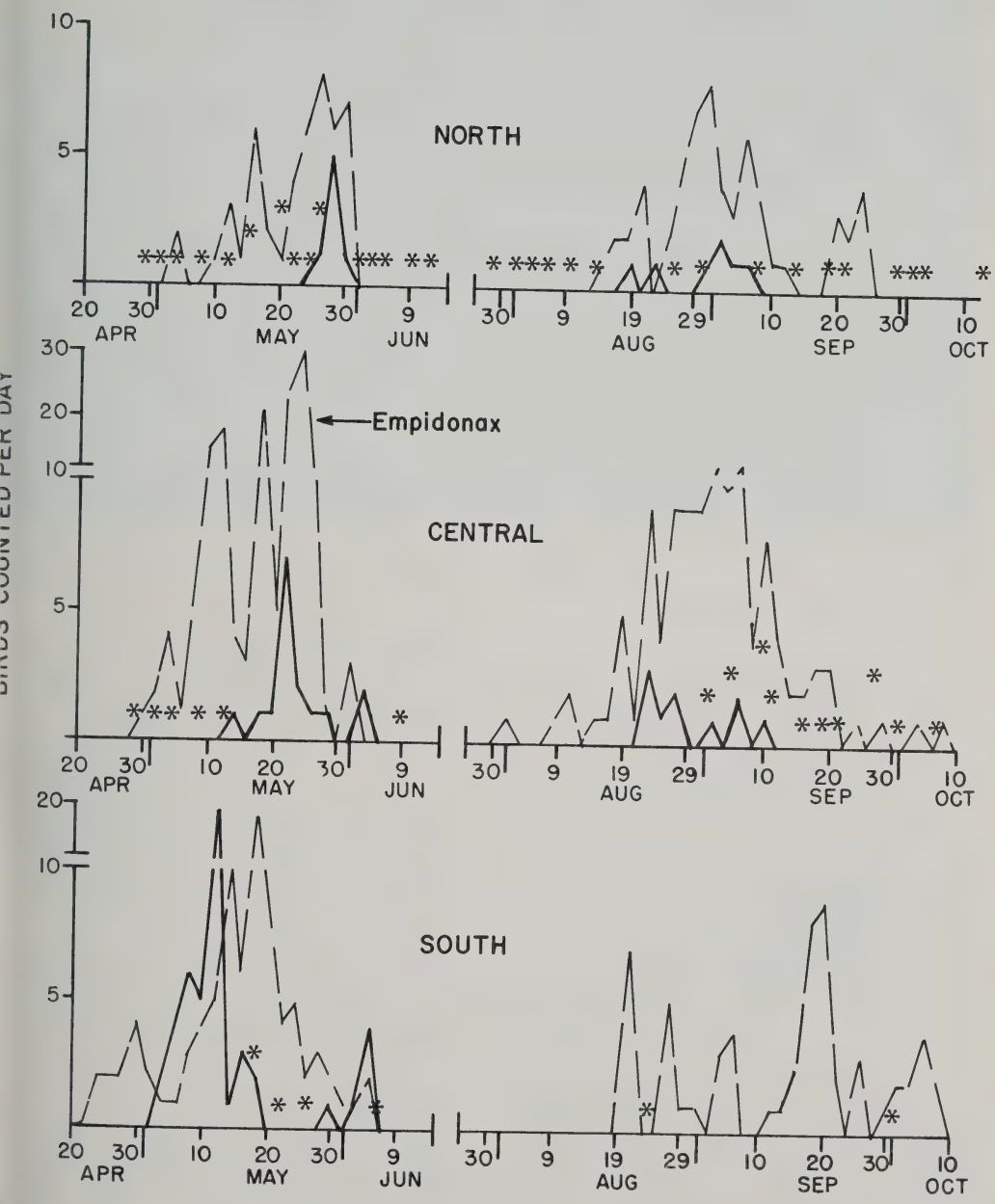


Fig. 26. — General distribution of the yellow-bellied flycatcher. outlined range may include large sections in which populations of species are thin or even absent because of the nature of the terrain paucity of suitable habitat.



ig. 27. — Migration seasons of the yellow-bellied flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) highest daily count of each 2 days (left scale). Asterisk symbols represent counts made in other years or by other observers. Dash line represents ts of unidentified *Empidonax* flycatchers; solid heavy line represents counts of identified yellow-bellied flycatchers.

Yellow-bellies probably occur throughout Illinois in migration, but the variation in populations from place to place is not known.

Though we did not often hear yellow-bellied flycatchers sing, we did hear them in all regions of the state, including the extreme south. The song was a softly uttered "too-reet" or "too-weeet," with only slight emphasis on the rising second syllable. More often fom yellow-bellies, we heard a call — "che-bunk" — similar to a single song phrase of the least flycatcher (Robbins et al. 1966).

The relatively large number of yellow-bellied flycatchers we identified in the south, versus central and northern Illinois, may indicate that we were confusing yellow-bellies with Acadians, a species particularly numerous in the south. However we do not believe this to be the case, because most of our identifications were based on calls. Yellow-bellied flycatchers were particularly vocal in the spring of 1970 when we were in southwestern Illinois, and the relatively high counts in the south may have been annual variation rather than regional variation.

The spring migration of the yellow-bellied flycatcher regularly extends into June even in the south (June 6), and at least as late as June 12 in the north (Ferry 1908).

The yellow-bellied flycatcher does not nest in Illinois (Fig. 26), and a specimen found dead near Palatine, Illinois on June 24, 1948 (Ford 1956) should be considered an abnormally late migrant.

Fall Migration

As do other species of *Empidonax*, yellow-bellied flycatchers begin their fall migration relatively early. Specimens have been found in northern Illinois, which is not more than 200 miles south of the southern edge of the breeding range, as early as July 29 and 30 (Brodkorb 1928, Bush 1920). They are of fairly regular occurrence in their migration through Illinois from early August (Ford et al. 1934, Brodkorb 1927) through September, with at least a few lingering into October even in northern Illinois (as late as October 12, Ford 1956). The earliest fall record known to us for central Illinois is August 23, and for the south it is August 25 (George 1968), but earlier August records will probably be recorded for both regions in view of the number of earlier records for the north (Ford et al. 1934, Clark & Nice 1950, Brodkorb & Stevenson 1934, Coursen 1947). George (1968) has records for the species in southern Illinois between August 25 and October 1 (Fig. 26).

As explained in the introductory paragraphs of this report, the fall counts of *Empidonax* flycatchers are even more problematical than the spring counts, partly because there is relatively little identifying vocalization by the birds in fall. Thus our fall counts of identified *Empidonax* are low (Fig. 27), and they probably do not accurately reflect the actual migration patterns. Our few fall observations suggest that the peak fall migration of the yellow-bellied flycatcher comes in late August and early September (Fig. 27), but the tower-kill data indicate strong migration even in late September.

At least 15 specimens of yellow-bellied flycatcher have been picked up from kills of night migrants a central Illinois television towers, on dates from September 2 through October 7. During the one night o September 26-27, 1972, five yellow-bellies were killed a towers between Monticello and Springfield, Illinoi (David Bohlen and James Seets, personal communica tions).

Because *Empidonax* flycatchers can be identified i the hand, netting operations seem to offer a bette method than direct field observation for the study of th migrations of these small flycatchers. In the Davenpor Iowa area between August 20 and September 25, 197 Petersen (1971) banded 22 yellow-bellied flycatcher about half of his spring catch (41 birds) for this species i 1968 (Peterson 1968*b*). For such netting studies to b useful for comparisons of spring and fall or othe populations, however, it is important to have continuo daily coverage.

Food Habits

One yellow-bellied flycatcher specimen examined b Forbes (1882*b*) had eaten beetles, which comprised ha of the stomach contents, and also Lepidoptera adults ar caterpillars.

ACADIAN FLYCATCHER

(*Empidonax virescens*)

(Fig. 28 and 29)

Spring Migration

The Acadian flycatcher regularly arrives about t third week of April in southern Illinois, the last of Ap in central Illinois, and the second week of May northern Illinois. The earliest recorded arrival dates a April 22 in the south, April 28 in central Illinois (Strau 1917), and May 6 in northern Illinois (Gault 1901). T peak of the Acadian's spring migration appears to occ about May 18 in the south, May 24 in central Illinois, a May 26-28 in the north (Fig. 30).

In the southern part of the state more Acadi flycatchers were counted in the spring on the western si of the state than on the east, in a ratio of about 3 (west) 1 (east). The difference probably reflects an actu difference in the amount of lowland forest in the t areas censused.

Distribution

The Acadian flycatcher is a bird of the eastern Uni States (Fig. 29). Acadians may nest in every county Illinois, but as yet the distribution is poorly known (F 31). The species is common in southern and cent Illinois in suitable habitat, but is rather rare in the nor The limit of its fairly common occurrence to the no seems to be the Illinois River. Excellent lowland forest

Fig. 28. — Acadian flycatcher on its nest. Photo taken in Pope
unty. Like other *Empidonax*, Acadians have whitish wing bars (just
ble over rim of nest) and a light eye-ring.

ıtral Lee County supports populations of less than 1
100 acres.

In addition to the plotted records (Fig. 31), there are
orts of nesting, without specific localities given, for
lhoun, St. Clair, and Madison counties (Richard
derson, personal communication).

sting Habitats and Populations

The Acadian flycatcher particularly favors damp
ests with understory in bottomlands. Forested streams
lmost any size are used by Acadians, and they follow
n the small spring branches well up into wooded hills,
, upland woods. Deep flooding of many major river
leys in Illinois in 1973 did not appear to deter
adians, as we observed good populations in flooded
sts where the water depth was at least 10 feet, and no
und was visible for a quarter of a mile or more. Floods
t kill the trees, however, destroy Acadian habitat,
ch is generally well-shaded, often with high mosquito
ulations. Acadians occupy the lowest tree canopy and
lerstory layers of the forest. Tree size and age
uirements of the habitat have not been studied, but
ıb habitat is definitely not suitable for Acadians.
Published population figures for the Acadian
atcher are mainly for central Illinois (Table 5). In 40
's of summer censuses of upland Trelease Woods near
ana, Kendeigh and his co-workers found this species
ent only 9 years (Table 5). Not far away, in
omland forest along the Sangamon River in Piatt
nty, Acadian populations varied from 8 to 32 birds

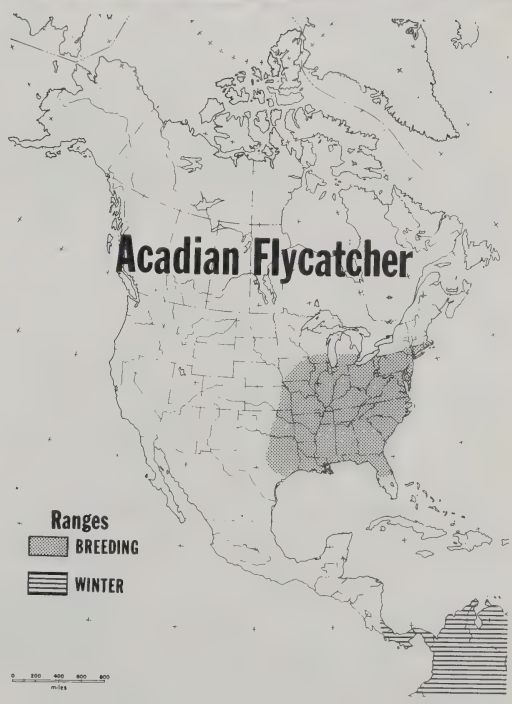


Fig. 29. — General distribution of the Acadian flycatcher. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and the paucity of suitable habitat.

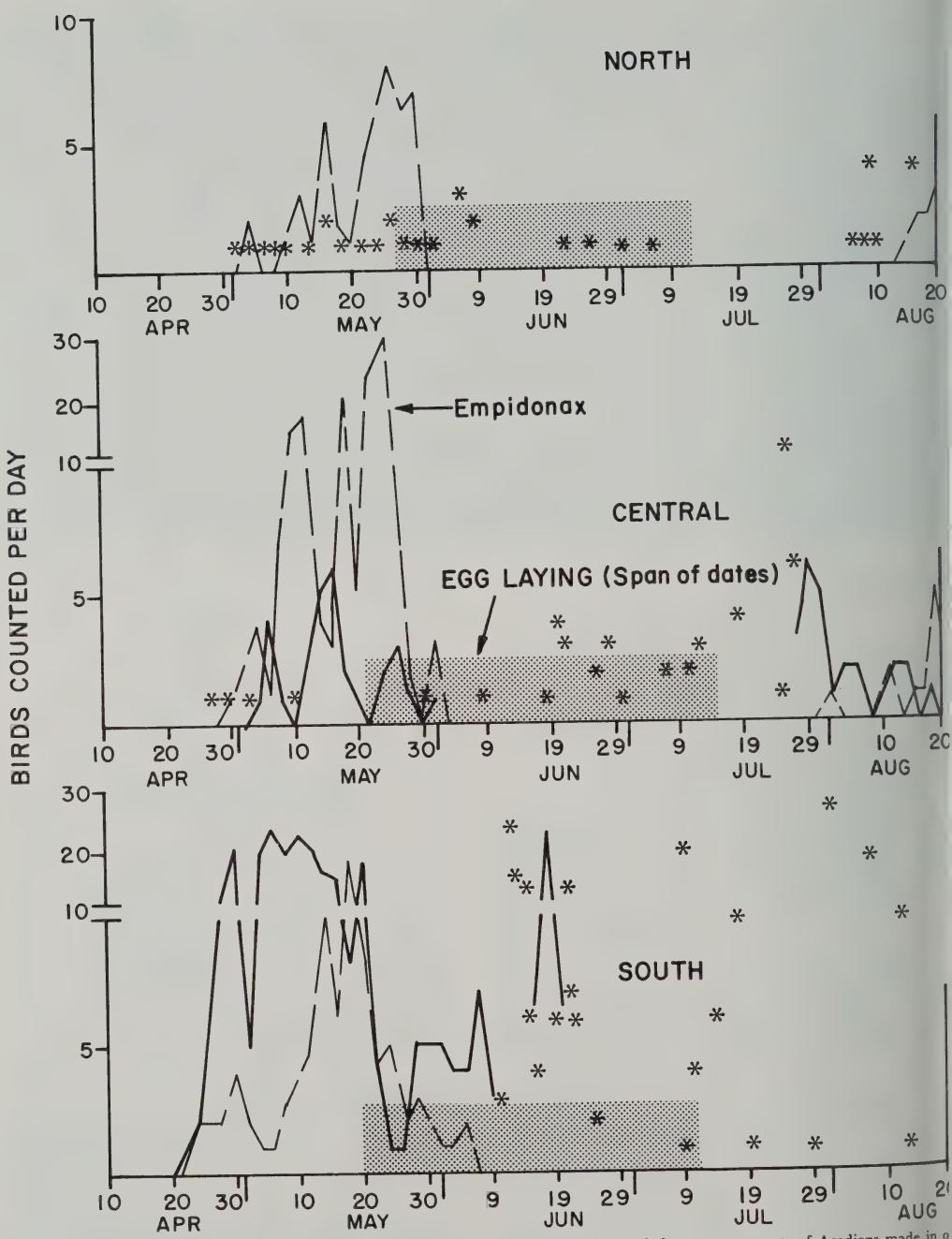
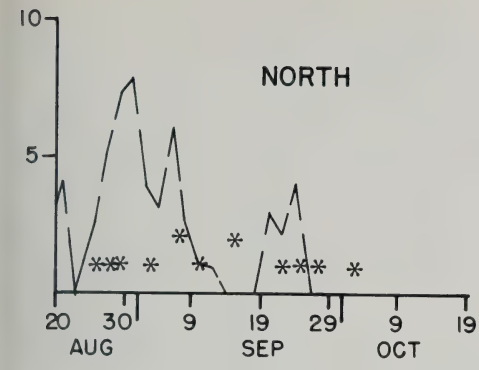
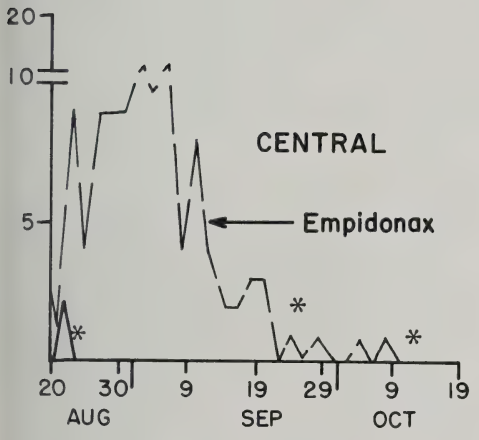
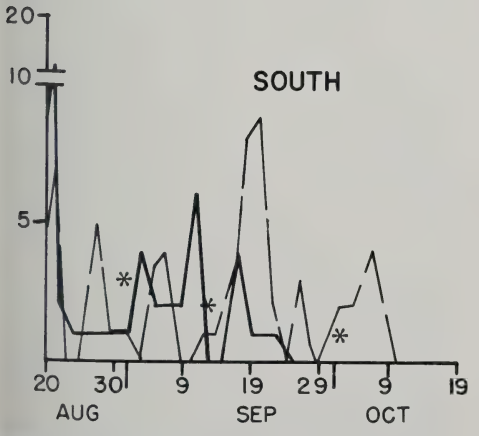


Fig. 30. — Egg-laying and migration seasons of the Acadian flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily counts of each 2 days (left scale). Asterisk symbols represent counts of Acadians made in o years or by other observers. Shaded areas show span of dates du which egg laying has been recorded. Dash line represents count







lentified *Empidonax* flycatchers; solid line represents counts of tified Acadian flycatchers.

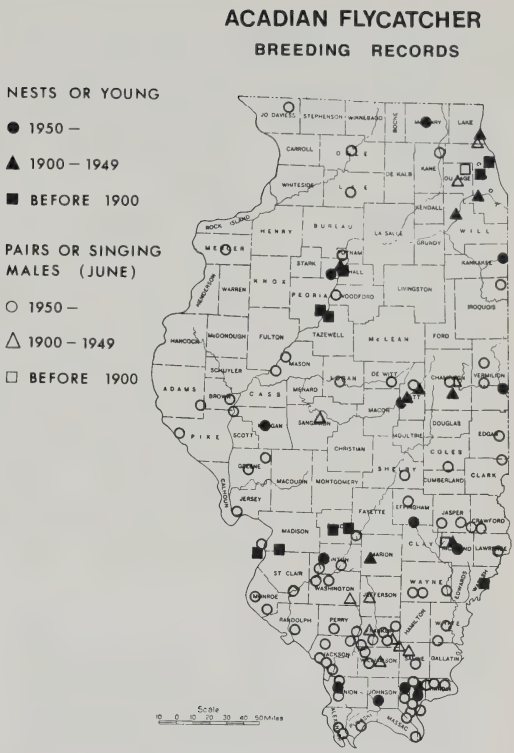


Fig. 31. — Breeding records for the Acadian flycatcher in Illinois. Singing male records cover the period June 1 to early July.

per 100 acres in different years, with adjacent upland forest populations as high as 24 Acadians per 100 acres (Fawver 1947*b*, Holmes 1950, Weise 1951). In excellent bottomland forest habitat in southern Illinois we have recorded Acadian populations as high as 32 birds per 100 acres (Table 5).

Four territories of Acadian flycatchers measured in floodplain forest in Piatt County varied in size from about 1.7 acres to 4.3 acres, averaging about 2.6 acres (Allison 1947, Fawver 1947*b*).

The Acadian flycatcher has undergone some notable population changes in the past century. Gault's unpublished notes of 1884-1927 indicate that the species was fairly common in DuPage and Cook counties. Woodruff (1907) also considered it not uncommon in northeastern Illinois. Ford (1956) called the Acadian an uncommon summer resident in the Chicago region. Judging from the frequency of reports of Acadians in literature, a population decline of the species took place in northern Illinois in the 1930's. In 1968, with extensive fieldwork in Whiteside, Carroll, and adjacent counties, we did not record a single Acadian flycatcher. The species may always have been rare (or absent) in northwestern Illinois, as up to 1904 Burtis Wilson had

TABLE 5. — Breeding populations of Acadian flycatchers in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Virgin floodplain forest	77	18	1948	Nest	Sangamon (C)	Snyder et al. 1948
Floodplain forest	50	8	1946	Nest	Piatt (C)	Fawver 1947*b*
Bottomland woods	15	46	1968	Nest	Vermilion (C)	Karr 1968
Bottomland woods	13	32	1973	Strip	St. Clair (S)	(This paper)
	10	30			Washington (S)	
Floodplain forest	16	6	1973	Strip	Franklin (S)	(This paper)
	20	10			Clinton (S)	
	21	14			Jackson (S)	
Oak-maple forest	55	2	1948	Nest	Champaign (C)	Kendeigh 1948
	55	4	1949		Champaign (C)	Kendeigh & Fawver 1949
	55	4	1950		Champaign (C)	Kendeigh et al. 1950
	55	4	1953		Champaign (C)	Kendeigh et al. 1953
	55	4	1956		Champaign (C)	Kendeigh & Brewer 1956
	55	4	1958		Champaign (C)	Kendeigh & West 1958
	55	+ [b]	1964		Champaign (C)	Kendeigh & Brooks 1964
	55	4	1966		Champaign (C)	Barnett & Balda 1966
	55	4	1970		Champaign (C)	Kendeigh & Clemens 197
Forest (all types including edge)	79	1	1957	Strip	North	Graber & Graber 1963
	97	5			Central	
	174	17			South	
	166	12	1958		South	

[a] All figures were converted to read birds per 100 acres (number of territorial males or nests X 2).

[b] Less than one.

recorded only one Acadian flycatcher in the Davenport, Iowa area (Hodges 1954). The Acadian population may now be increasing in the north. Petersen (1964) reported that the species was spreading into new areas near Chicago, and Gauthreaux (1971) stated that the species is making a recovery in northeastern United States.

Acadian flycatchers almost always place their nests near the end of a horizontal limb of a sapling, often along a rivulet or stream and sometimes over the water.

We have nest-site data on 41 Acadian nests in southern (mainly) and central Illinois. Over half the nests (22) were in maples, particularly sugar maples (*Acer saccharum*). Six nests were in ironwood (*Ostrya virginiana*), five in oaks (*Quercus stellata, Q. alba, Q. muhlenbergii*), four in blue beech (*Carpinus caroliniana*), two in elms (*Ulmus rubra*), and two in willows (*Salix* sp.). Whether the high proportion of sugar maples used represents definite selection on the part of Acadians, or only a high incidence of that tree species in the habitat we cannot say.

Nest heights varied from 5 to 35 feet, and averaged 12 feet.

Nesting Cycle

As there are no published banding data on the Acadian flycatcher in Illinois, homing has apparently not been demonstrated for any Illinois population.

The Acadian flycatcher has at least two song forms. The most commonly heard is an unmusical, quick, high, emphatic "flee-deet" or "flee-eetit" of two or three syllables often so run together that they sound like one, with rising inflection on the second part. The earliest Acadian arrivals sing this song, and we have heard it late as September 25 in southern and central Illinois.

The second song is part of an entrancing display, ar consists of a prolonged, high, soft, twittering sound, trill, uttered by the male as he flies a somewhat circul course through part of his nesting territory, alightir here and there, usually briefly, on twigs as he goes. Tl fight is distinctive, a kind of fluttering, slow-motic flight, and the song is not interrupted when the bi perches.

Besides the songs, Acadians commonly utter a sha call note, a "quip" or "squeep" sound, which is probab an alarm note. It is most often heard near the nest.

Nesting activity must begin shortly after the fema arrive, as we have observed nest building as early as M 5 in southern Illinois. The nest, constructed of grass fine branchlets, forest duff, moss, spider web, and ster oak catkins, is unique in form (Fig. 28). Though Acadi nests are often rather fragile looking, they have a toug rigid construction from the interlacing of branchl which are almost wire-like. The nest is almost alwa somewhat pensile, suggesting the structure of a vireo ne but shallow. It is usually placed in one of the termir forks of a horizontal branch of a sapling. Some Acadi nests are so thin walled that the nest contents can be se through the bottom from below the nest. Some Illin nests also have a much more massive, thick-wall construction, like nests of the species from southeastern United States, as illustrated in Bent (194 There is almost always some trailing material hangi from the nest. The material, usually grass stems, m hang as much as 1-2 feet below the nest (Hess 1910). T

ves the nest an unkempt appearance, which, nificantly, resembles the debris left hanging in trees er a flood. The structure of the Acadian's nest may is be a kind of mimicry, related to the regular spring oding of Illinois streams, and may also account for the ular location of nests within the floodplain.

The time requirement for nest construction is not curately known. One nest in southern Illinois was gely completed in 6 days.

Mumford (1964), who worked with a banded pulation of Acadians in Michigan, found that both st building and incubation were carried out by the nale alone.

The egg-laying season extends from May 20 or earlier central and southern Illinois and May 28 in the north at least July 12-15 in all regions of the state (Fig. 30). nsidering the laying dates for 62 eggs, we judge that peak of egg production in southern Illinois comes ween May 28 and June 7. The few laying records ilable for central and northern Illinois indicate a peak ring the period of June 1-15.

During incubation some female Acadians are very acious to the nest, and will snap their bills at human ervers, often refusing to move even when touched.

The most frequent clutch size for the Acadian atcher in Illinois is 3 eggs. Twenty-seven clutches n nonparasitized nests in all regions of the state wed the following distribution: 5 eggs — 1 (about 4 cent), 4 eggs — 4 (15 percent), 3 eggs — 21 (78 cent), 2 eggs — 1 (4 percent). We suspect that 2-egg tches are actually more frequent, and 5-egg clutches frequent, than these figures indicate. The 5-egg set collected by P. W. Smith, Jr. in Bond County in 5;we have never found a clutch this large. On the er hand, we have seen a number of nests with 2 eggs, none which we observed from the onset of laying.

H. M. Holland (in Bent 1942) determined the ıbation period at one central Illinois nest to be 13 s. In Michigan Mumford (1964) and Walkinshaw 51) recorded incubation periods for the Acadian atcher of 13-15 days, most frequently 14.

Nestling life lasts at least 13 days. At a nest in thern Illinois, two 13-day-old nestlings which we dvertently frightened from the nest could not sustain ht and merely fluttered to the ground. Thus for a cies that often nests over water, 13 days would seem an lequate nestling period. In Michigan Walkinshaw 51) determined 14 days to be the most frequent ling period.

Considering the observations above, we estimate that nesting cycle, from the onset of nest building to the ging of three young, requires about 36 days.

We have laying histories for only 12 Acadian nests, all ope County. The incidence of cowbird parasitism in sample was high — 50 percent. Cowbird parasitism cadians has been recorded in all regions of the state, there are too few nests with known histories to uate the effects of the cowbird on a poplation basis.

Data on one of the Pope County nests indicates that host young do not survive in a successfully parasitized nest. In this nest two Acadians and one cowbird hatched on the same day, but only the cowbird survived to fledge. Mumford (1964) witnessed much the same thing at a nest in which a cowbird hatched more than a day ahead of three Acadian young. The Acadian nestlings died, appearently from neglect, because the cowbird usurped the food supply. Though Acadians raise some cowbirds, they also apparently resist parasitism to some degree. Bendire (in Friedmann 1963) described an Acadian nest in which a second floor had been built to cover a cowbird egg. An Acadian nest in Piatt County was deserted with four cowbird eggs and one host egg (Allison 1947).

There are no adequate data on nesting success for any Illinois population of Acadian flycatchers. In our small sample of Pope County nests, only 25 percent fledged flycatchers and 10 percent fledged cowbirds. The causes of nest failure are also largely unknown.

A stub-tailed juvenile Acadian collected in southern Illinois August 11 (U.S. National Museum 60892) is probably indicative of the end of the nesting season. Fawver (1947*a*) last saw an adult male on territory in east-central Illinois on August 7. In southern Illinois we have seen singing males still on territory at least as late as September 25.

Fall Migration

The fall migration of Acadian flycatchers may begin as early as late July and early August (Fawks 1968*b*). As discussed earlier, identification problems make the study of fall migration of *Empidonax* very difficult. Based on the relatively small numbers of *Empidonax* identified, the peak in fall numbers of Acadians came between August 20 and September 20 (Fig. 30), but the actual pattern of the Acadian's fall migration is essentially unknown and better techniques of study, such as netting operations, are needed.

The last dates Acadians have been reported are October 3 in northern Illinois (Gault, unpublished notes 1888), October 12 in central Illinois, and October 2 in the south (George 1968).

Though there are a few reports of Acadian flycatchers being killed at television towers (Parmalee & Parmalee 1959, Parmalee & Thompson 1963), the identity of the birds is in question. All tower-killed specimens that we have examined to date have proved to be either least, yellow-bellies, or Traill's. Gastman (1886) writes of an Acadian killed on an electric light tower in Decatur on September 29, but it has not been possible to verify the identity of this specimen.

Food Habits

Five stomachs of Acadian flycatchers examined by Forbes (1878) all contained insects, Coleoptera being the principal item. Obviously more complete studies are required.

TRAILL'S FLYCATCHER Complex—

WILLOW FLYCATCHER (*Empidonax traillii*)
ALDER FLYCATCHER (*Empidonax alnorum*)

(Fig. 32 and 33)

Spring Migration

Determining the migration patterns of any *Empidonax* flycatcher is difficult because of the identification problems. The Traill's flycatcher complex is even more complicated than the rest, because the tw species are so nearly identical.

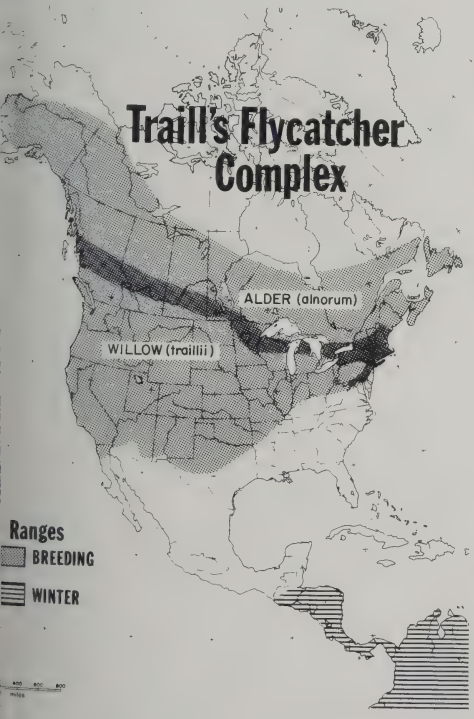
The most distinctive characteristic of the two is t song, often phoneticized "fitz-bew" for the willo flycatcher, and "fee-bee-o" for the alder flycatche Morphological characteristics of the two forms overl greatly, and even with specimens in hand we have be uncertain about identification of some specimens. Th dependence on the birds' singing for identificati complicates the study of migration of the two form

Fig. 32. — Traill's flycatcher at its nest. Like other *Empidonax*, Traill's have a light eye-ring and whitish wing bars.

cause neither is strongly vociferous in migration. The ngs are not loud, and as Traill's flycatchers are late ring migrants, arriving when many other species are in l song, there is a good possibility that Traills' songs are en "covered up." However that may be, the vast ajority of *Empidonax* seen are not singing, and cannot assigned a specific population identity. If, for ample, we state that the more northern-ranging alder catcher is a later spring migrant than the local eeding willow flycatcher, the statement does not take o account the possibility that the silent *Empidonax* uld be predominantly alders.

Prior to now the Illinois literature has treated the aill's complex as one species (see explanation of recent ssification in the introduction of this report), and very authors who discussed Traill's flycatchers mentioned song form. In our discussion, we also treat the nplex mainly under the name of Traill's flycatchers, d the reader must bear in mind that two very closely ated species are included.

Traill's flycatchers of both species are known to be ht migrants in Illinois. Arrival of Traill's flycatchers in nois as early as April 24 (Musselman 1934-1935) is



ig. 33. — General distribution of Traill's flycatchers. The outlined e may include large sections in which populations of the species are or even absent because of the nature of the terrain and paucity of ble habitat. The ranges of the two species of Traill's flycatchers are ly known. The two are sympatric at least in places along the le-shaded band.

probably exceptional, and even April 29 (Widmann 1907, Fawks 1956) is early for the species. The earliest spring specimen we've examined (U.S. National Museum No. 108366), from Warsaw in central Illinois, was taken May 3 and is a willow flycatcher. Widmann (1907) found Traill's flycatcher to be very regular in its appearance in the St. Louis area on May 4 or 5. We suspect that the early arrivals are likely to be willow flycatchers. Most of the Traill's population, however, arrives after May 12 in southern Ilinois, and after May 20 in central and northern Illinois (Fig. 34).

The spring migration of Traill's regularly extends well into June, and possibly into July, even in the south (Fig. 34). The consistent peak in numbers of Traill's flycatchers in the three regions in early June (Fig. 34) includes local breeding birds (willow flycatchers) and probably also passing transients of both the "fitz-bew" (willow) and "fee-bee-o" (alder) song forms. In the St. Louis area both forms have been heard in May, the alders being present only about a week while passing through, with the willow flycatchers remaining throughout the summer (Jones 1953). James Funk (personal communication) has heard the alder song in southern Illinois (Union County) on May 20, and in central Illinois on May 28 (Adams County) and June 3 (Champaign County). Robert Russell has observed that the willow flycatcher usually arrives in northern Illinois by the second week in May, while the (singing) alders arrive about the end of May and reach peak numbers June 6-8, when Russell heard as many as six singing (Kleen & Bush 1971*a*). An alder which we found in Iroquois County on June 22 appeared to be on terriotry but subsequently disappeared, leaving only nesting willow flycatchers in the area. This June 22 record may not be particularly late migration in Illinois for either population, as we have recorded willow flycatchers arriving on nesting territories in early July in east-central Illinois. We also have a female specimen of the alder flycatcher (INHS #7) taken June 25, 1967 in central Illinois.

In summary, the spring migration of willow flycatchers in Illinois lasts from about May 1 to July 1, and the migration of alders from as early as May 20 into July.

Distribution

The general distribution of Traill's flycatchers is shown in Fig. 33. The alder flycatcher is the more northern-ranging of the two species and the willow flycatcher the more southern- and western-ranging. Where the breeding ranges of the two forms overlap both in Canada and the United States (Stein 1963) the species apparently retain their integrity.

The breeding distribution of Traill's flycatchers in Illinois is shown in Fig. 35. All of the nesting "Traill's" which we have observed in Illinois, in all regions of the state and in all habitats, have proven to be the willow flycatcher.

Alder flycatchers have been known to nest as close as

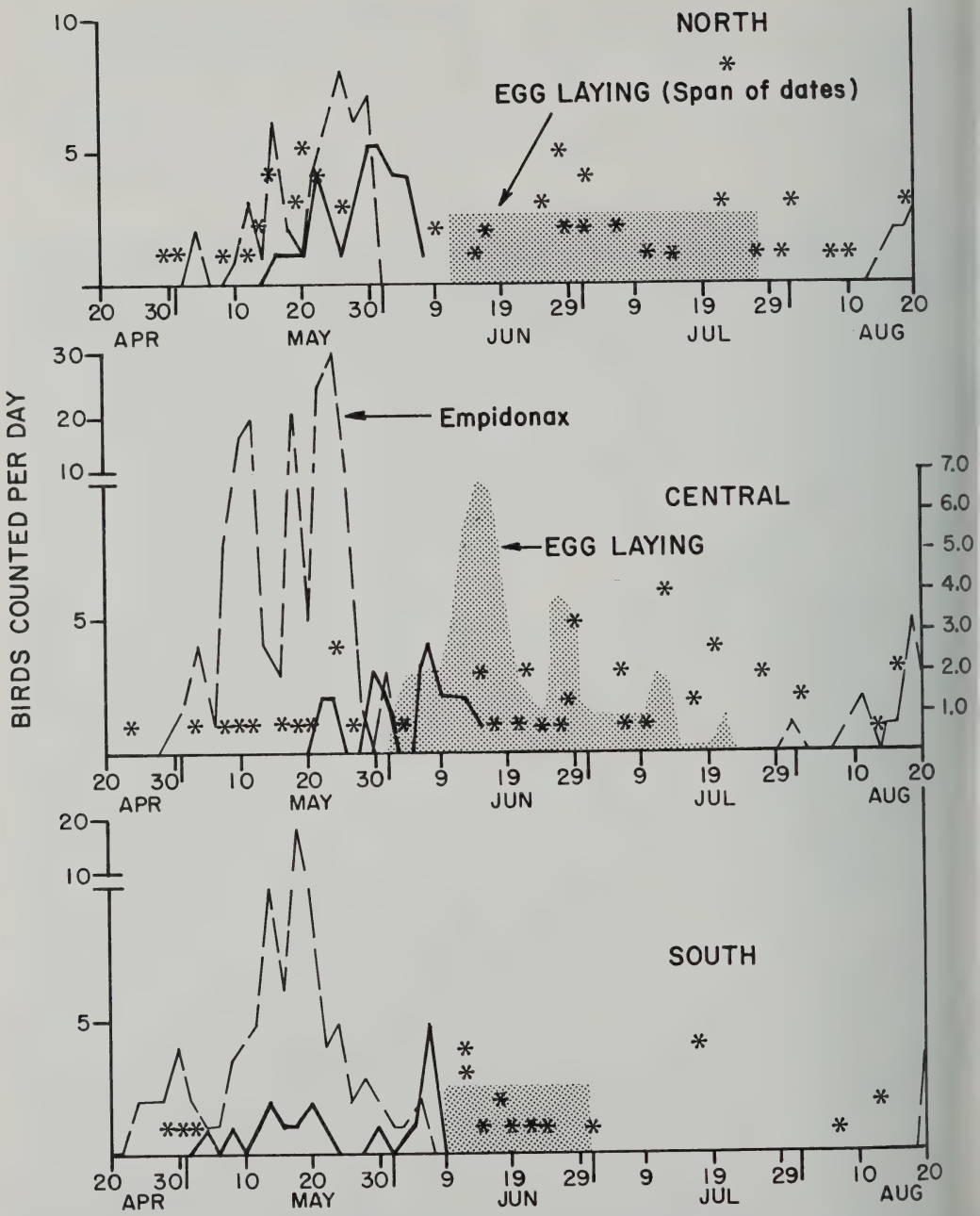
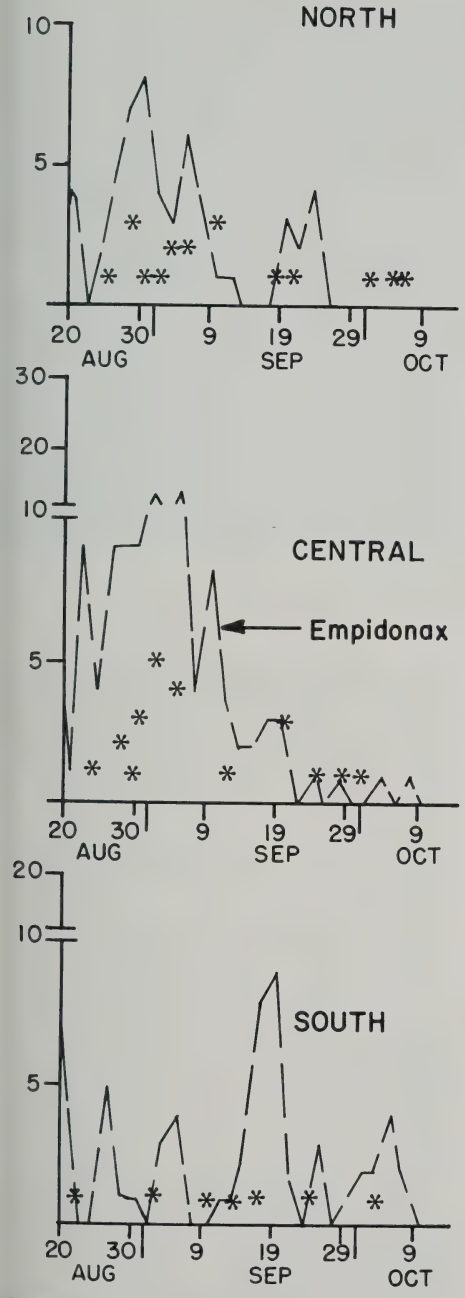


Fig. 34. — Egg-laying and migration seasons of the Traill's flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily counts of each 2 days (left scale). Asterisk symbols represent counts made in other years or by observers. Shaded areas show the percent of eggs laid on a given (right scale), or the span of dates during which egg laying has



ded. Dash line represents counts of unidentified *Empidonax* :chers; solid heavy line represents counts of identified Traill's :chers.

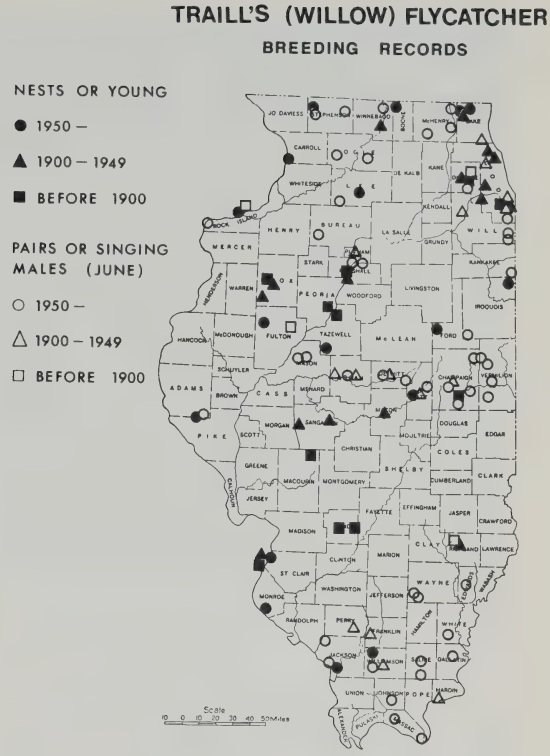


Fig. 35. — Breeding records for the Traill's flycatcher in Illinois. Singing male records cover period June 1 to early July.

central Wisconsin, and Stein (1963) suggested that the alder formerly nested in northern Illinois. The alder flycatcher may yet be found nesting in Illinois, but to date there is no firm proof of breeding for this species in the state. The presence of an alder flycatcher singing in Iroquois County in late June, as mentioned above, we have interpreted as representing late migration. One other observation is suggestive of alder flycatcher nesting: In a population of Traill's flycatchers nesting at the edge of Spring Lake (Carroll County) in 1968, one nest was built which had the structure and appearance of a nest of the alder flycatcher (Fig. 36). The eggs, however, were typical willow flycatcher eggs, and no song of the alder flycatcher was heard in this population. Thus, despite the appearance of the nest, we concluded that it belonged to a willow flycatcher.

The willow flycatcher may nest in every county in the state, but the breeding distribution is spotty and very poorly known.

Nesting Habitats and Populations

In Illinois the willow flycatcher most often nests in shrub areas or clumps of young trees. Widmann (1907) described the original habitat as trees bordering rivers,

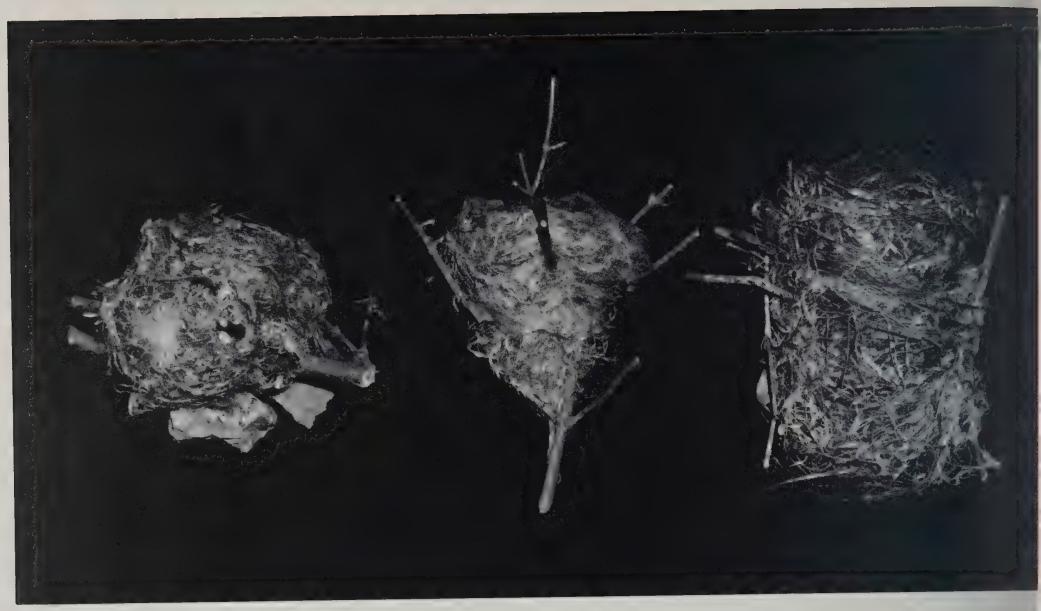


Fig. 36. — Variation in nest structure in a single population of Traill's flycatchers in Carroll County. The population occupied lowland wil habitat, and was of the "fitz-bew" (willow) song form. Nest at right resembles alder flycatcher nest.

creeks, and lakes, or willow clumps in swampy places, and added that the species has adapted to orchards, city parks and cemeteries as well as trees and shrubs along country roads. Ridgway (1889) in the south and Barnes (1890) in central Illinois both considered Traill's (willow) flycatcher to be especially an orchard species, yet the later statewide censuses indicated that Traill's flycatchers were not at all common in Illinois orchards (Forbes & Gross 1921, Graber & Graber 1963). The Ridgways (1889, 1915, 1923) also had Traill's flycatchers nesting on their suburban estate in southern Illinois one season (Table 6) and suggested that the species was quite tolerant of humans. Loucks (unpublished notes, 1889) and Goff (1932) both found nests in cities (Peoria and Rockford) but there is probably no urban population of Traill's flycatcher in Illinois now, perhaps because cities have changed in character a great deal since the 1930's.

During the nesting season, we have almost always found Traill's flycatchers in open (nonforested) country in the following situations: (1) willow clumps in low-lying or flat land — stream bottoms, drainage ditches, marshes, etc., (2) upland shrub areas, and (3) roadside shrubs and hedges, both upland and lowland. In southern Illinois south of the latitude of Jackson County we have found breeding Traill's flycatchers only in lowland habitat, not in the ample areas of shrub-covered hills, a situation used regularly by Traill's to the north. On strip-mined land, Karr (1968) found good populations of Traill's in central Illinois (Table 6), but Brewer (1958) found none in this type of habitat in southern Illinois. There are no measurements of Traill's flycatcher populations for southern Illinois. In lowland willow clump habitat Cook County, Herbert Stoddard estimated the June 1 population of Traill's flycatchers to be 25-30 pairs square mile, the equivalent of 8-9 birds per 100 a (Ford 1956). Traill's flycatchers are usually absent fr or at best uncommon, in the forest edge habitat; W (1951) recorded 2 birds per 100 acres in forest edge Piatt county.

Hedgerows of osage orange were often considered important habitat for Traill's flycatcher. Silloway (18 and Willard (1898), respectively, defined the favo habitat to be untrimmed hedges of two to four seas growth, and hedges not more than 15 feet tall. west-central Illinois (Knox County) Harold M. Holl (unpublished notes, 1942) recorded six pairs of nest Traill's flycatchers in about one-fourth mile of os hedge (48 birds per mile). In east-central Illinois (F County) we found much lower densities in about 5 lin miles of osage hedge — four pairs in 1958 (1.5 birds mile), and three pairs in 1959 (1.2 birds per mile). searches of hedgerows in other areas of Illinois have le to believe that the population densities observed in F County are quite representative of recent population Traill's in this habitat. We have seen no population compared with the 48 birds per mile observed Holland, yet we believe his observations to be true feel that all of the observations indicate a general dec in population of Traill's flycatcher over the years. have already mentioned the change in orc populations. Where we found low populations east-central Illinois hedges, Hess (1910), like Hollan

TABLE 6. — Breeding populations of Traill's flycatchers in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
rly shrub	21	38	1966	Nest	Vermilion (C)	Karr 1968
rub grown areas	15	7	1957	Strip	North	Graber & Graber 1963
	17	6	1958		North	
	15	7	1957		Central	
burban residential	8	25	1915	Nest	Richland (S)	Ridgway 1915
ampy prairie	64	6	1942	Nest	Sangamon (C)	Robertson 1942*a*
rshland	29	3	1957	Strip	North	Graber & Graber 1963
land second growth hardwoods	56	4	1944	Nest	Sangamon (C)	Robertson 1944*b*

[a] All figures were converted to read birds per 100 acres (territorial males or nests X 2).

st-central Illinois, found Traill's to be an "abundant" ecies in hedgerows and orchards. We cannot explain e change. In addition to the declining population nsities in hedgerows, the hedges themselves are rapidly ing destroyed. There is no evidence to indicate that aill's populations in the lowland willow habitat have dergone declines similar to that of the hedge pulations.

The specific identity of the Traill's flycatchers that st in hedgerows is something of a mystery. This pulation has largely disappeared in recent years, and e song form was apparently never recorded. From the en nature of the habitat and the geographic range we d expected the hedgerow population to be willow catchers, but nests and eggs of Traill's flycatchers in e State Museum collected by H. M. Holland from dgerows in west-central Illinois are not typical of the llow flycatcher. These specimens show some aracteristics (e.g. whitish, finely spotted eggs; coarsely nstructed nests) of the alder flycatcher. These features highly variable in willow flycatcher populations, wever, and we suspect that the hedgerow populations l prove to be willow flycatchers. The question needs to resolved with careful study soon, before the hedgerow catchers disappear completely.

The list of plants recorded as nest sites for Traill's catchers in Illinois (Table 7) is probably incomplete. st nests have been recorded in osage orange and lows. The high number of nests recorded in osage ticularly is probably not representative of the actual tribution of nests by plant species, but more likely lects the fact that hedges were convenient places for ogists to search for flycatcher nests, especially in past ades. We do not know how the state population of aill's is distributed by habitat.

On the heights of Traill's flycatcher nests Silloway 94) and Willard (1898) agreed that nests in st-central Illinois were usually 3-10 feet high, rarely her. Records of nest height, including our own, show a ge from 3 to 25 feet, with the greater height being e. Twenty-three nests in northern Illinois averaged 6.2 t in height and 37 nests in central Illinois averaged 6.6 t.

Territory size for the Traill's flycatcher has apparently never been measured in Illinois. The clumps of shrubs that serve as nest sites are often surrounded by acres of open-field habitat of one sort or another, so that nesting pairs are often naturally spaced by the vegetation. Neither the minimum distance between nests nor the spacing of nesting vegetation has been measured precisely.

Nesting Cycle

There are no published banding data to show homing by Traill's flycatchers in Illinois.

Silloway (1894) rarely found Traill's flycatchers on their territories in Macoupin County before the second week of June, and we have observed equally late or even later arrivals (early July) of nesting Traill's flycatchers to hedgerows in east-central Illinois.

Much has been written about the variation in song of Traill's flycatchers (see especially reviews by McCabe 1951, and Stein 1963). Though we have never witnessed the song flight described by McCabe, our observations in

TABLE 7. — Plants used by Traill's flycatchers as nest sites in Illinois.

Species	Number of Nests (Total 73)
Osage orange (*Maclura pomifera*)	35
Willow (*Salix* sp.)	10
Mulberry (*Morus* sp.)	6
Dogwood (*Cornus drummondii*)	5
Elderberry (*Sambucus canadensis*)	3
Maple (*Acer negundo*, and sp.)	3
Alder (*Alnus* sp.)	1
Apple (*Malus* sp.)	1
Basswood (*Linden* sp.)	1
Elm (*Ulmus* sp.)	1
Grape (*Vitis* sp.)	1
Hawthorn (*Crataegus* sp.)	1
Hazel (*Corylus americana*)	1
Honey locust (*Gleditsia triacanthos*)	1
Honeysuckle (*Lonicera* sp.)	1
Plum (*Prunus* sp.)	1
Shingle oak (*Quercus imbricaria*)	1

Illinois are in general agreement with those of McCabe for Wisconsin. The song of Illinois breeding populations (willow flycatcher) is the so-called "fitz-bew" type, and sounds the same in all regions of the state. Each student seems to have his own phonetics for this song (McCabe 1951), and though we have used the more or less standardized phrase "fitz-bew" in referring to the willow flycatcher song, we prefer our own version of the phonetics ("pit-beer" or "fitz-your"). To us the song seems to have an "r" ending. This song phrase is very often preceeded by a quick, angry note — "frit," or "creet," as McCabe has described it. This "frit" note may or may not be part of the song. Sometimes it is the only note we hear from territorial birds, and it may be uttered over and over again, with pauses between notes. Thus, uttered by itself, it seems more like an alarm note than a song. In conjunction with the usual song phrases, this "frit" note is usually uttered only once (sometimes two and rarley even more times). If it is considered to be part of the song, then the song may have from two to four, or even more phrases, but usually it is either "pit-beer" (the basic song) or "frit — pit-beer" with a slight pause between the first and second phrase. When we record the song and play it back to nesting birds they almost invariably respond quicky by approaching our position. Often the recording does not induce singing, but only the "frit" call note, which suggests that it is an alarm note. Another note often heard from Traill's is a rather soft "whit," or "whip" as McCabe (1951) designates it. This also seems to be an alarm note for nesting birds, but it is also uttered frequently by unidentified migrant *Empidonax* flycatchers, and we do not know that it is exclusively the vocabulary of Traill's.

There are no published data on the time requirements for the nesting cycle of Traill's flycatchers in Illinois. One northern Illinois nest that we observed was completed from an early stage of construction in 5 days, before the first egg was laid. Another nest which lacked only a lining went 4 days before the first egg was laid. The incubation and nestling periods combined for one nest that fledged four young in northern Illinois was 27 days. From these data, one nesting cycle for a Traill's nest with four eggs would require about 35-36 days. Goff's (1932) data indicated that nestling life was at least 13 days. There are few actual nest records for southern Illinois, and essentially no data on the nesting cycle for that region.

Traill's nests are either built in an upright fork of a shrub or tree, or saddled on a horizontal branch (Fig. 32 and 36). According to Silloway (1894), Willard (1898), and Loucks (unpublished notes, 1889), Traill's flycatcher nests are made of grayish bark fibers, dried weed stems, fine grass, feathers, and gossamer, with a lining of fine grass, horse hair, and feathers. Nests of more recent years generally lack the horse hair. The nests often have a silvery appearance (Fig. 36), and resemble nests of the yellow warbler (*Dendroica petechia*), and goldfinch (*Spinus tristis*). We have seen one Illinois nest (Fig. 36) that closely resembled the alder type, as illustrated by Stein (1958). The variation in nest structure that we saw in a single population in northwestern Illinois ne Savanna (Fig. 36) was as great as we have encountered the entire state.

Egg laying by Traill's flycatchers has been recorded central Illinois between June 3 and July 21, and northern Illinois between June 11 and July 27 (Fig. 34 The peak of laying occurred between June 11 and 19 central Illinois (Fig. 34) and is apparently only slight later in the north (Beecher 1942).

Data from the literature, old museum records, ar our own notes on 48 Traill's flycatcher nests with eg show that the clutch size in central and northern Illinois almost always either 4 eggs (about 70 percent), or 3 eg (about 30 percent). The average for all clutches was 3 eggs with no significant difference between central a northern Illinois nests. In central Illinois, Strumbe (1883) also found that most Traill's nests (65 percer received 4 eggs, but Silloway's (1894) data showed predominance of 3-egg clutches (76 percent of all ne with eggs), perhaps reflecting annual variation. In 18 and 1886 in Bond County, P.W. Smith, Jr. found at le two nests with 5-egg clutches (Chicago Museum Natural History Set Nos. 9386 and 9387), but such lar sets must have been exceptional even then. Strumbe (1883) also reported a nest with 7 eggs, apparently t work of two females.

Traill's flycatcher must be very uncommo parasitized by cowbirds in Illinois, as we know of but o other record (Poling 1889) than the one reported Friedmann (1963).

We see no evidence that Traill's flycatchers try more than one brood. Though the egg-laying curve central Illinois shows minor peaks in late June and J (Fig. 34), these peaks probably represent re-nestir following nest failures, as they are not spaced adequat to be second broods. Silloway (1894) also believed th only one brood was reared.

There are no published data on nesting success productivity for any Illinois population of Trai flycatcher. We have histories on only 16 nests, mainly northern Illinois in 1968, and they had poor success: percent of nests (27 percent of eggs). Causes of n failure were unknown, but most nests failed in the stage. A nest that Goff (1932) observed lost two of its f young in a windstorm, but ultimately the remaining t were successfully fledged. Gross (1925) mentioned that found high mortality (in three out of four nests) nestling Traill's flycatchers in central Illinois from he mite infestations.

Fall Migration

The problem of field identification of sil *Empidonax* flycatchers has already been discussed (in introduction and in the section on the yellow-bell flycatcher) and we have relied primarily on captured collected specimens for the fall graph points in Fig.

In central Illinois Varner indicated, apparently fr netting observations, that the peak of the Traill's migration came in late July and early August (Fa 1966*b*, 1968*b*), but other observations indicate

cidedly later fall migration for the species. Just how e Traill's flycatchers may be found on their nesting ritories has not been determined, but considering ing dates as late as July 27 (Fig. 34) we might expect at at least a few Illinois birds would still be occupied h nesting until about September 1. In Wisconsin Cabe (1951) found that regular singing by Traill's catchers ended August 9-11. We have heard the aill's flycatcher song (species ?) but once in September, the 5th at Urbana, Illinois.

At least 15 specimens of Traill's flycatchers have been ked up, with other nocturnal migrants, at television vers in central and northern Illinois on dates between gust 31 (INHS specimen), and October 7 (Petersen 59). We have examined 12 of these specimens, and all t one appeared to be alder flycatchers. This is in ping with our general impression that in tower kills rthern forms tend to be more prevalent than southern ms. On one night, September 1-2, 1972, at least 5 ers, all immatures, were killed at towers in central nois. A kill on the night of September 20-21, 1966, oduced two immature alders and one adult willow catcher.

We do not know if there is a difference in the timing the fall migration of the two species. For the Traill's nplex, the peak of the fall migration probably occurs ate August and early September, or possibly even later g. 34). The northern Illinois specimen of October 7 is latest Illinois record of which we know.

Both adult and immature specimens taken in otember show only very few pin feathers in the body mage, most notably the throat, suggesting that the lt may be largely finished in August. One adult male, en August 31, was in worn plumage however, with no lt in evidence. We could not certainly identify the bird o species.

od Habits

Two specimens of Traill's flycatchers examined by bes (1882*b*) had eaten insects exclusively, one fourth ng canker worms, and one-third Ichneumons. other one-fourth of the stomach contents was beetles, about one-tenth was ants and other Hymenoptera.

AST FLYCATCHER (*Empidonax minimus*)

(Fig. 37 and 38)

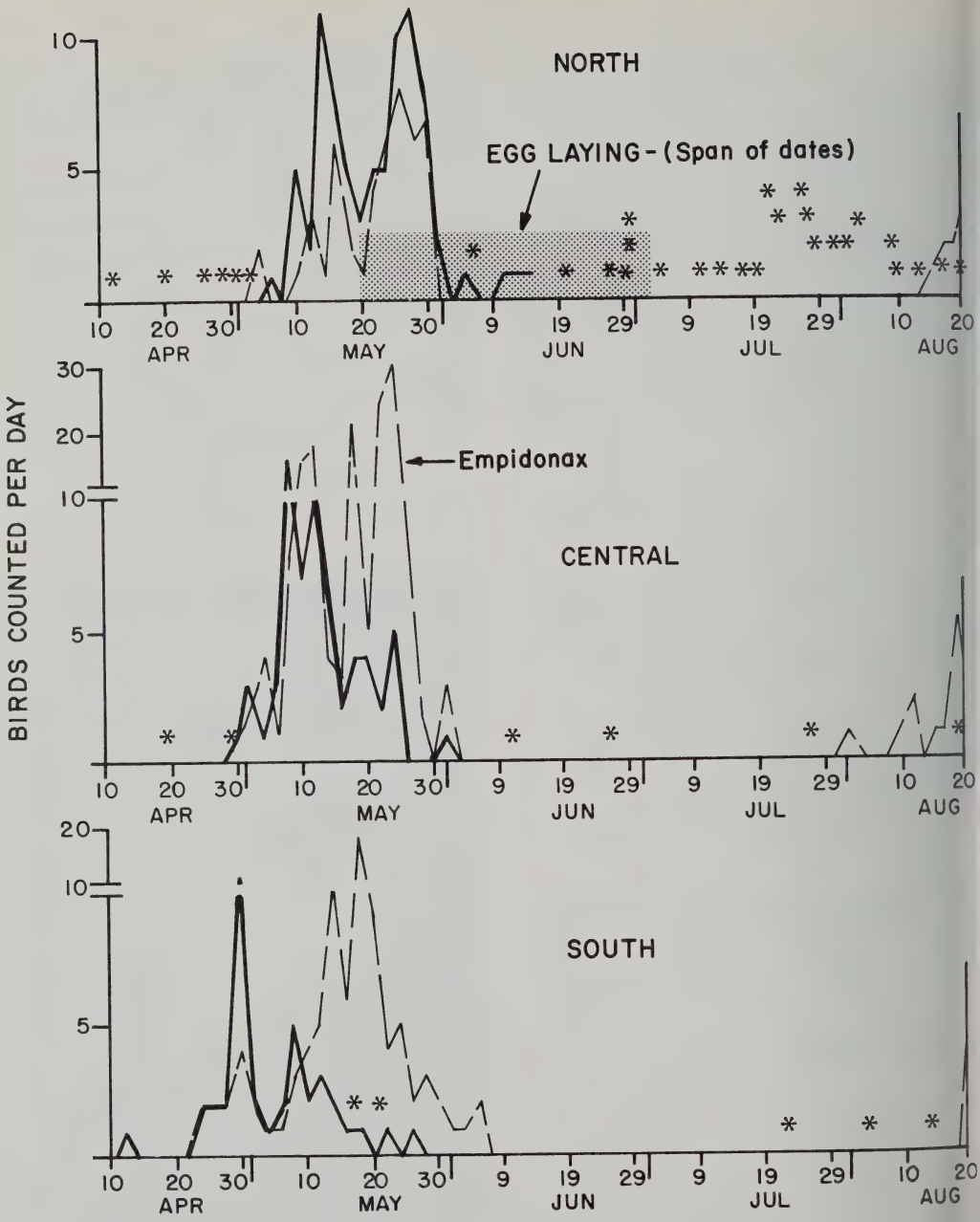
ing Migration

The earliest recorded arrival dates of least flycatchers llinois, April 11 for southern Illinois (Fig. 39) and il 12 for the north (Walter & Walter 1904), are ably exceptional, and the alleged arrival date of ch 30 for the north (Abbott et al. 1933) is probably error. Usually least flycatchers are not found in the until late April or early May, with peak numbers ring April 28-May 10 in the south, May 7-16 in ral Illinois, and after May 10 in the north (Fig. 39). migration in central and northern Illinois extends June, and in the north a relatively small number remain to nest (Fig. 39). The species has also been recorded in the St. Louis area as late as June 3 (Widmann 1907).

Distribution

The least flycatcher is a nesting species of the northern United States and Canada. It winters in Mexico and Central America (Fig. 38). In Illinois the species may nest as far south as Marshall County where Barnes found a nest in 1910 (Illinois State Museum specimen) and Iroquois County where we have found singing territorial males in recent years (Fig. 40). There are no authentic records of nests in central Illinois. The listing of this species as a breeding bird in Hancock County (American Ornithologists' Union 1957, George 1971) is apparently based on the fact that Worthen collected it at Warsaw during the "breeding season" (Widmann 1907). The McLean County record (American Ornithologists' Union 1957) and a Clinton County record (Anonymous 1917) lack substantiation. The listings of the species in the breeding bird census at Decatur (Chaniot & Kirby 1955) and in "summer census" at Urbana (Wandell 1948) are

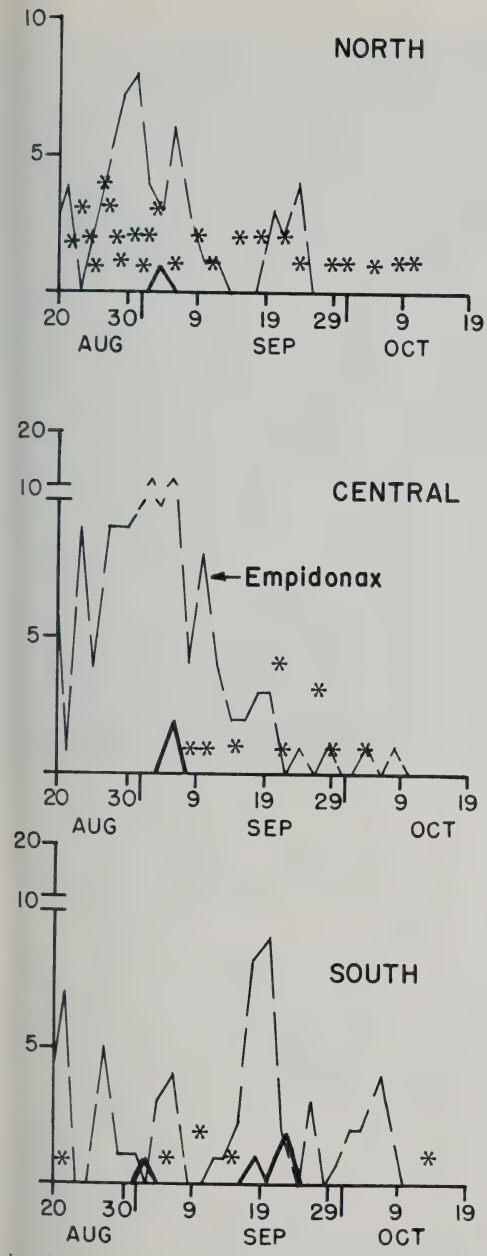
Fig. 37. — *Empidonax* species. This small flycatcher is representative of the genus, species of which are best identified in the field by their song.



probably due to the fact that study periods cover time during which the least flycatcher is migrating. This is certainly true of Finley's (1917) report which lists this bird as a summer bird at Normal but has recorded it May 5-11. The paucity of least flycatcher records in northwestern Illinois (Fig. 40) may only reflect inadequate exploration.

Nesting Habitats and Populations

The least flycatcher in Illinois is a bird of the ecot forest edge, and places of similar form such as open sh areas, parkland, well-planted residential areas, and the past at least, orchards. The only actual measuren of a least flycatcher population in Illinois was tha



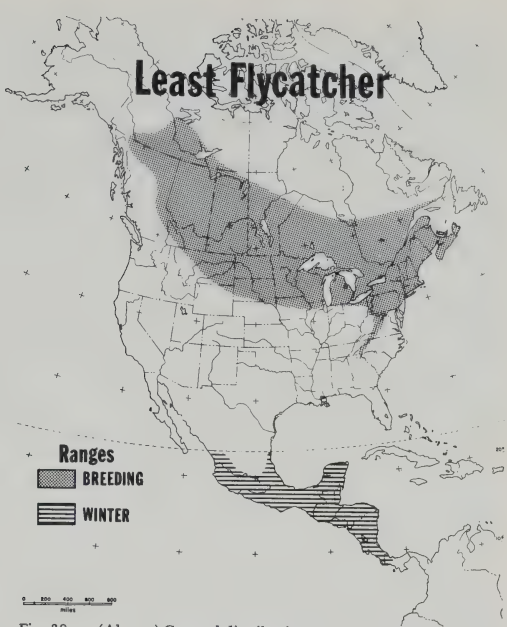


Fig. 38. — (Above.) General distribution of the least flycatcher. The outlined range may include large sections in which populations of the species are thin or even absent because of the nature of the terrain and paucity of suitable habitat.

Fig. 39. — (To left, graph starting on page 44.) Egg-laying and migration seasons of the least flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily counts of each 2 days (left scale). Asterisk symbols represent counts made in other years or by other observers. Shaded area shows span of dates during which egg laying has been recorded (north only). Dash line represents counts of unidentified *Empidonax* flycatchers; solid heavy line represents counts of identified least flycatchers.

cher (1942) who found two nests in 27.67 acres of lified (residential) woodland.

Nelson (1876-1877) considered the least flycatcher to comon summer resident in northeastern Illinois. The breeding record for Chicago, according to Ford & nont (1949) was in 1904. Ford (1956) called the ies uncommon, and formerly more common. Nice (1945) considered the species endangered in Illinois. Accurate population trends cannot be determined without more actual population measurements.

Nesting Cycle

Little has been published on the breeding biology of the least flycatcher in Illinois, and a thorough study of the species here at the southern edge of its range is definitely needed.

The distinctive song, phrased "che-bec," is heard in all regions of the state as soon as the bird arrives. The transients may sing only hesitantly, repeating the song only a few times, but the nesting birds in the north repeat the song quickly over and over again.

The time requirement for nest construction is unknown. The nest, which superficially resembles a Traill's flycatcher nest (Fig. 36), is often placed in a small tree near the end of a limb. Nest heights have been recorded from 2 to 20 feet above ground. Only three nest trees have been identified — apple, oak, and willow.

Egg laying has been recorded from May 20 to July 3

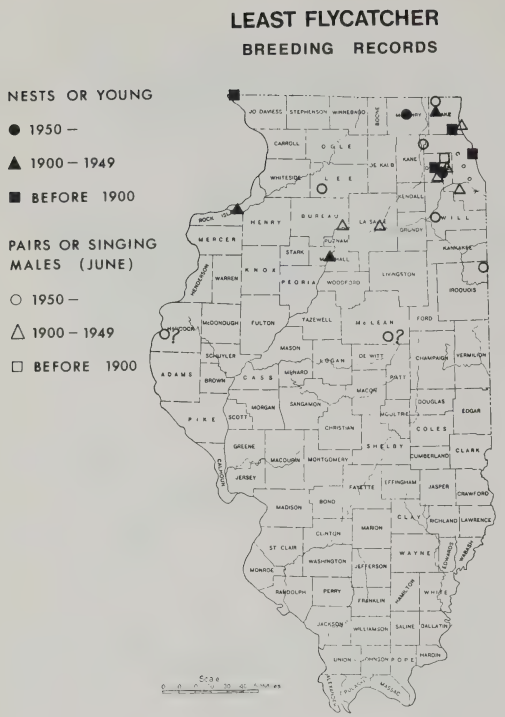


Fig. 40. — Breeding records for the least flycatcher in Illinois. Singing male records cover the period June 1 to early July.

(Fig. 39). The average clutch size for 11 nests, all having either 3 or 4 eggs, was 3.6 eggs.

The time requirements for incubation and nestling life have not been determined, nor are there quantitative data on nesting success or productivity.

Fall Migration

Records for adult least flycatchers in southern Illinois (well south of the breeding range) on July 22, August 4 (Kleen & Bush 1971*b*), and August 14 (U.S. National Museum specimen) indicate how early the fall migration of this species begins. The two August specimens were both adult females, and the August 4 specimen still showed a brood patch and slightly enlarged ovary (2.5 x 5mm). It was also in worn breeding plumage, though showing some signs of the molt on its body. Despite these remnant signs of breeding, we believe the bird to be definitely a migrant. This seeming haste to inititate the fall migration is puzzling, especially as the species' migration is also quite prolonged in the fall.

Migration of least flycatchers is apparently nocturnal. At least 11 specimens (both sexes, adults and immatures) have been picked up from bird kills at television towers in central Illinois in 5 different years (Brewer & Ellis 1958; Parmalee & Parmalee 1959; unpublished records, 1966, 1968, 1972). The dates of kills for least flycatchers were from September 10 to 29. Four females (two adults, tw immatures) were killed at two towers in Piatt an Champaign counties on one night, September 20-2 1966. The peak of the fall migration for the le flycatcher, as for other *Empidonax*, cannot determined from our field censuses because of t problem of making specific identifications. The le flycatcher's fall migration probably regularly extends in October, with records as late as October 9-10 in northe Illinois (Ford 1956, Coursen 1947, Mark Swan perso communication, 1971), and October 14 for the southe region (Cooke 1888). A record for October 29 in northe Illinois (Dillon 1968) is an exceptionally late departu

Food Habits

Almost nothing is known of the food habits of t least flycatcher in Illinois. Forbes (1878) examined stomachs of leasts, but provided no information on da or places of collection. All of the birds had eaten inse — Coleoptera were found in 8 stomachs, Hymenoptera 2, and Lepidoptera in 2. No specific identifications w provided. Gault (unpublished notes) examined stomach of a May specimen from Cook County and fou it filled with beetles, but here also more spec identifications are lacking.

Clearly, all aspects of the biology of the le flycatcher in Illinois are badly in need of study.

EASTERN WOOD PEWEE (*Contopus virens*)

(Fig. 41 and 42)

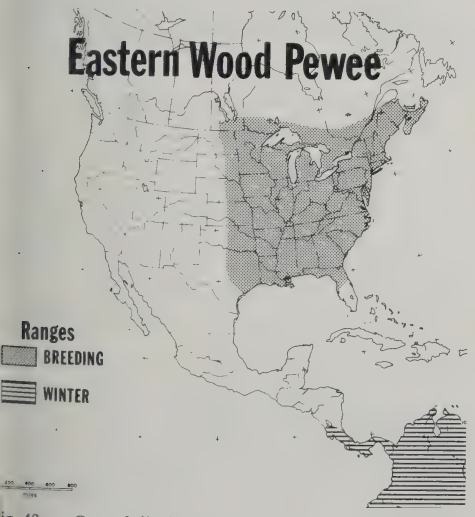
Spring Migration

The eastern wood pewee is a nocturnal migrant Illinois, as indicated by specimens killed at night central Illinois television towers. We know of only killed in the spring — on the night of May 27-28, 19 Whether pewees also migrate by day is apparen unknown.

Returning from the wintering grounds, the first w pewees do not usually reach Illinois until after April (Fig. 43), and though there are a number of publish records for the pewee earlier than April 15, even central and northern Illinois (Silloway 1902, Hess 19 Kauffman 1917, Bartel & Reuss 1932, Abbott et al. 19 Duncan 1934-1935, Smith 1942), we suspect that th records are erroneous or accidental. To some extent th excessively early records for the "pewee" may stem fro confusion of names. Particularly in the older literatu the name "pewee" was often applied to the east phoebe. It is also possible that some of the early rec were based on "pewee" songs uttered by starlings, wh are excellent mimics of the pewee.

Even for southern Illinois, records for the wood pe as early as April 12 and 14 (James Funk, and Mich Morrison, personal communications) are probably exceptional, and late April or early May arrivals are n representative (Fig. 43, Cooke 1888). In central Illi the wood pewee has been detected as early as april 20 22 (L.B. Hunt personal communication, Smith 19

ig. 41. — Eastern wood pewee on its nest. Photo taken in Pope County. Slightly larger than *Empidonax* flycatchers, this drab flycatcher has wing but lacks a distinct eye-ring.



ig. 42. — General distribution of the eastern wood pewee. The ded range may include large sections in which populations of the es are thin or even absent because of the nature of the terrain and ity of suitable habitat.

but in most years the arrival is first noted in early May (Smith 1930, Musselman 1921*a*). In northern Illinois Walter & Walter (1904), and Johnson (1936) recorded pewee arrivals on April 27 and 28, but the species is more often first detected after May 5 (Brodkorb 1926*a*, Bartel 1932, Ford et al. 1934, Clark & Nice 1950).

Our counts showed peaks in the spring population between May 8 and 18 in southern Illinois, May 20 and 26 in central Illinois, and May 28 and June 3 in northwestern Illinois (Fig. 43). The spring migration probably extends into June even in southern Illinois.

As in the case of the crested flycatcher, the spring population of the wood pewee was low in the northwest by comparison with those in central and southern Illinois. We did not see consistent differences in the spring populations of pewees between eastern and western Illinois, though our highest counts of this species, in contrast to the crested, tended to be in the east.

Distribution

The breeding range of the eastern wood pewee is the eastern half of the United States and adjacent southern Canada (Fig. 42). In Illinois the pewee almost certainly nests in every county, but actual nesting records are still lacking for some counties (Fig. 44).

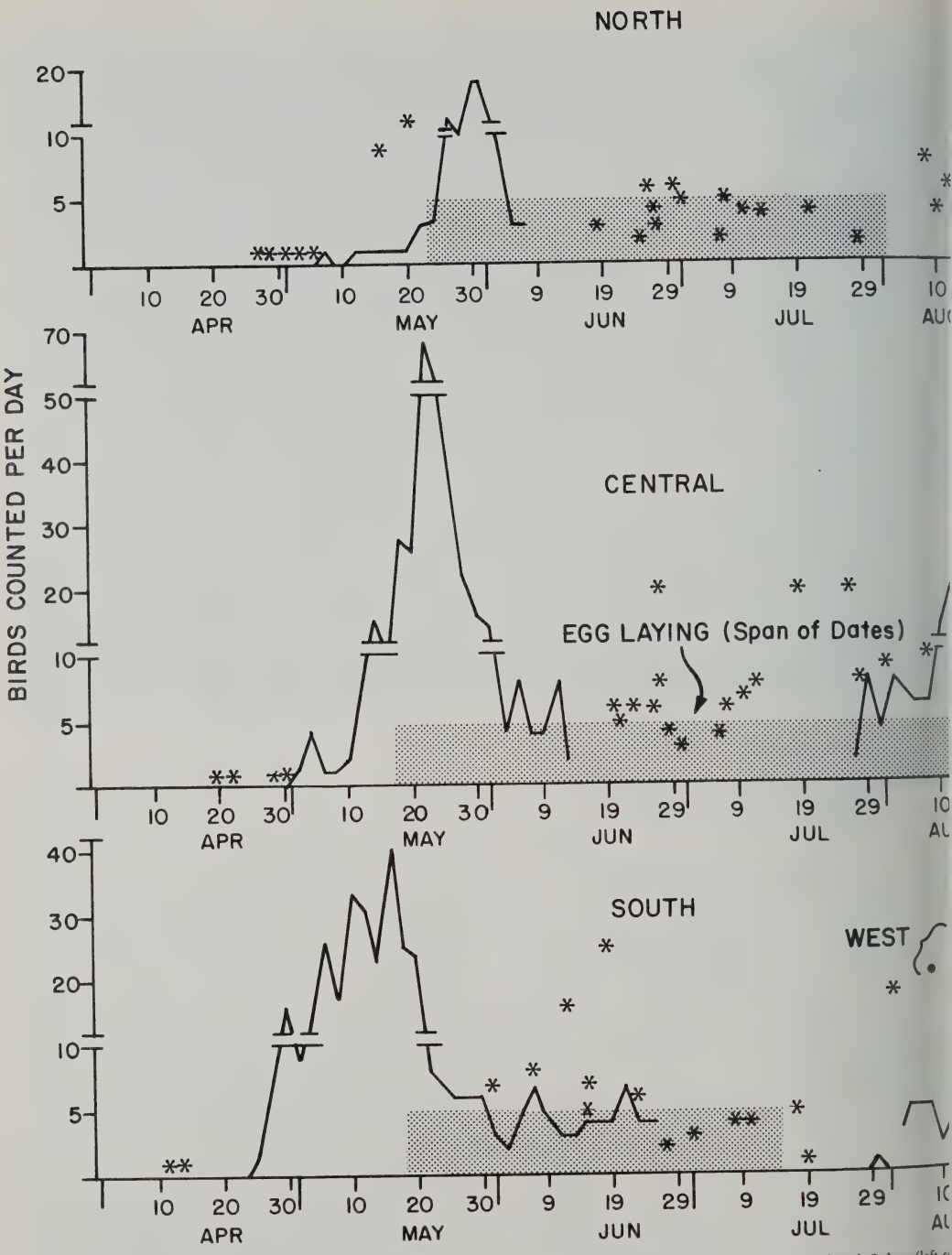
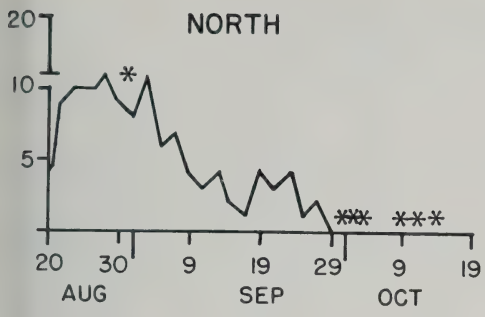
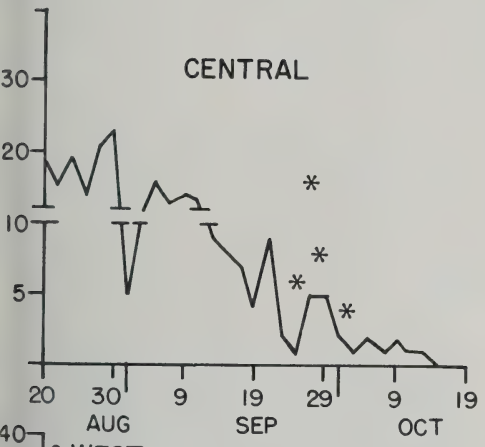
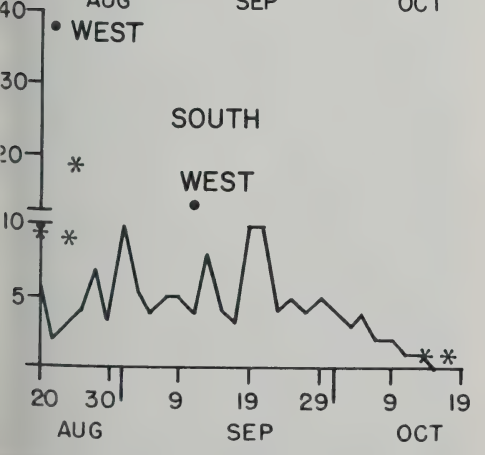


Fig. 43. — Egg-laying and migration seasons of the eastern wood pewee in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily counts of each 2 days (left s Asterisk symbols represent counts made in other years or by







vers. Shaded areas show span of dates during which egg laying has recorded.

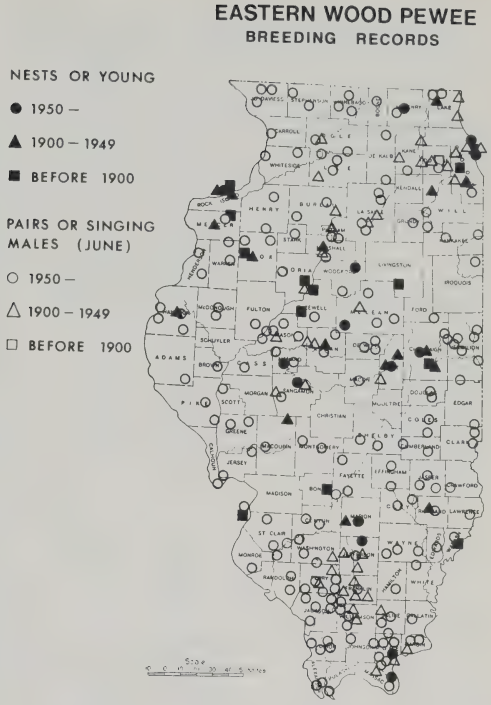


Fig. 44. — Breeding records for the eastern wood pewee in Illinois.

Nesting Habitats and Populations

The eastern wood pewee is a forest and forest edge species, foraging especially in openings in the lower edge of or just below the lower tree canopy. Impressions as to the precise characteristics of the habitat have varied widely. Barnes (1890) and Gates (1911), both working near the Illinois River, and Fawver (1947*b*) near the Sangamon River, all considered bottomland forest to be the primary habitat for pewees, while Hankinson (1915) in Coles County and Ries & Werner (1946) near the Illinois River considered upland forest to be the favorite habitat. Fawver (1947*a*) and Carpenter (1935) considered the wood pewee a forest-edge species. The pewee nests in all of these habitats including forest interior, and has good population densities in each (Table 8), but it is not certainly known whether pewees have a definite preference for one forest situation over another. Mundt (1883) found pewees plentiful in Livingston County in not too dense timber of medium-sized trees, especially oaks. Swink's (1960) observations on perching sites also show the wood pewee to be strongly associated with oaks. Swink (1960) and Ridgway (1889) also point out that pewees often perch on dead branches.

We have nest tree data for only 27 nests, about half of which (52 percent) were in oaks, including bur oak (*Quercus macrocarpa*), white oak (*Q. alba*), black oak

TABLE 8. — Breeding populations of eastern wood pewees in various Illinois habitats.

Habitat	Acres	Birds Per 100 Acres[a]	Years	Type of Census	Region or County	Reference
Suburban residential	8	50	1914	Nest	Richland (S)	Ridgway 1915
Parkland estate	100	10	1915	Nest	Cook (N)	Eifrig 1915
Second growth hardwoods	15	67	1937	Nest	Rock Island (N)	Fawks 1937
	15	67	1938		Rock Island (N)	Fawks 1938
Upland second growth hardwoods	56	7	1941	Nest	Sangamon (C)	Robertson 1941
	56	7	1942		Sangamon (C)	Robertson 1942*b*
	56	7	1944		Sangamon (C)	Robertson 1944*b*
	46	4	1948		Sangamon (C)	Robertson & Snyder 19
Oak-maple forest	55	11-72 (avg 37)	1927-1972	Nest	Champaign (C)	Kendeigh 1944, 1948
Maple-elm forest	63	28	1950	Nest	McLean (C)	Calef 1953
	63	20	1951		McLean (C)	
Upland oak-hickory forest	24	21	1967	Nest	Hancock (C)	Franks & Martin 1967
Unmodified woodland	27	15	1937	Nest	Lake (N)	Beecher 1942
Modified woodland (human housing)	28	22	1937	Nest	Lake (N)	Beecher 1942
Bottomland forest	15	38	1966	Nest	Vermilion (C)	Karr 1968
Virgin floodplain forest	77	28	1948	Nest	Sangamon (C)	Snyder, et al. 1948
Floodplain forest	50	24	1946	Nest	Piatt (C)	Fawver 1947*b*
Grazed bottomland woods	93	26	1955	Nest	Macon (C)	Chaniot & Kirby 1955
Forest (all types including edge)	79	9	1957	Strip	North	Graber & Graber 196
	98	6	1958	Strip	North	
	97	9	1957		Central	
	117	10	1958		Central	
	20	5	1907		South	
	40	10	1909		South	
	174	8	1957		South	
	166	3	1958		South	
Late shrub	21	10	1966	Nest	Vermilion (C)	Karr 1968
Shrub areas	35	6	1958	Strip	Central	Graber & Graber 196
	39	2	1909		South	
	67	1	1957		South	
	62	5	1958		South	

[a] All figures were converted to read birds per 100 acres (territorial males or nests X 2).

(*Q. velutina*), and post oak (*Q. stellata*). Most of the others were in maples, including sugar maple (18 percent), elms (15 percent), and willows (11 percent). Pewee nests are usually placed fairly high. Illinois nests have ranged form 9 feet to about 50 feet and averaged 25 feet in height.

In southern Illinois Brewer (1958) found no significant numbers of pewees in stands of trees less than 21 years old in strip-mined areas. We see no indication that pewees still nest in orchards as they apparently did in Ridgway's (1887) time. We also suspect that the pewees found in shrub areas (Table 8) are foraging, and not nesting birds. Pewees also nest in towns, as Hess (1910), Gates (1911), and Ford (1931) stated, but urban populations have not been measured and we suspect that they are very low. Ridgway's (1915) density figure for a suburban population (50 wood pewees per 100 acres) in Olney, Illinois is probably exaggerated because of the small acreage censused. The density values for small census areas (especially under 20 acres) tend to be high regardless of the habitat (Table 8).

Territories of wood pewees in lowland forest measured by Fawver (1947*b*) and Calef (1953) in central Illinois ranged from 1.4 to 3.1 acres and averaged 2.9 acres (1946), 1.9 acres (1950), and 2.7 acres (1951), with territories being smaller in years of higher populations and larger with lower population densities. Twomey's (1945) measurments of territories were apparently ba on a different interpretation of the territory, for he g figures of about 6 acres (1934) and 8 acres (1935).

Nesting Cycle

Eastern wood pewees probably sing regularly du their spring migration, and they arrive in Illinois sing The common song is unmistakable: a clear, plaint wiry whistle — "p-e-e-e- a- wee," long and drawn with major emphasis on the first syllable (Ridgway 18 Nice (1961) pointed out that the pewee has at least other song forms, a two-syllable "peee-oh," or "peee- which we have often heard also, and a more com "twilight" song which we have never heard. Ridg (1889) also refers to a twittering sound that the pe utters. Eastern wood pewees sing almost throughout day (Nice 1961).

When and where pair-formation of pewees t place we do not know, but in some instances the p seem to be formed almost as soon as (or perhaps before) the birds arrive on their nesting areas. Sillo (unpublished notes, 1921) observed a pair in Peori May 5, which is close to the early arrival date (Fig. 43 central Illinois Fawver (1947*a*) observed pe establishing territories in mid-May. The process invo some rigorous fighting among the pewees.

The nest, with rare exception as noted by G

)17), is saddled on a horizontal branch and is a very eresting structure (Fig. 41). It is composed of weed ms, dry grasses, hair, and cobwebs, and covered with hens (Loucks unpublished notes, and Sanborn & elitz 1915). At a distance the nest resembles a knot on branch. The time required for nest construction has been recorded.

Egg laying by wood pewees begins at least as early as y 23 in northern Illinois and May 17 in central Illinois, probably earlier in the south even though present ords do not show it (Fig. 43). Egg laying has been orded at least as late as August 12 in central Illinois, ing the wood pewee an egg-laying season about as long that of the phoebe, but much later (Fig. 18 and 43). do not know if the wood pewee is double brooded.

Egg data on 35 Illinois nests (north-13, central-17, th-5) indicate that most nests (69 percent) receive 3 s (Fig. 45). Other clutch sizes were 4 eggs (17 percent), ggs (11 percent), and a few nests (3 percent) with 5 s. These data represent mainly old museum records or literature and may not constitute a truly resentative sample, especially for recent years. The e requirements for incubation and nestling life have been studied in Illinois.

Nice (1961) studied parental care of nestlings at a d pewee nest in northern Ilinois. She observed that y one parent — probably the female — brooded the ng, but both adults shared, about equally, the task of ling the young. When the nestlings were about 12-13 s old, the parents brought food to the nest at rates ying from 14 to 55 times per hour (average: 29). The ling rates were lower (average: 16 times per hour) n the nestlings were younger (5-11 days old). Nice 61) found that most of the nestlings' food was minute,

Fig. 45. — Eastern wood pewee nest and eggs.

but there were a few relatively large items such as a cabbage butterfly, a damsel fly, and a crane fly.

Nice (1961) also observed that the parent wood pewees were very belligerent in the vicinity of the nest, driving away gray squirrels (*Sciurus carolinensis*) and birds larger than themselves as well as other pewees. They were particularly aggressive toward squirrels, grackles (*Quiscalus quiscula*), blue jays, and robins (*Turdus migratorius*), but tolerant of the smaller species such as house sparrows and red-eyed vireos (*Vireo olivaceus*). In central Illinois Fawver (1947*b*) saw wood pewee conflicts with cardinals (*Cardinalis cardinalis*), and black-capped chickadees (*Parus atricapillus*). In the south we have seen wood pewees vigorously chasing Acadian flycatchers.

There have been no measurements of nesting success or productivity of pewees, and there are no data on causes of nest failures. Neither is it known whether wood pewees attempt to rear more than one brood. The wood pewee has been recorded as a victim of cowbird parasitism in Illinois (Green 1917, Friedmann 1963), but the incidence and effect of parasitism is unknown for any Illinois population.

Fall Migration

The eastern wood pewee has been an uncommon victim in the kills at television towers. The four fall specimens, which have been retrieved from central Illinois towers, were killed between September 17 and October 1, indicating that active migration was in progress at least during that period.

Our highest fall counts, as well as those of Swink (1960) and Dillon (1968), for the wood pewee (Fig. 43) came in August, and we believe that the fall migration of the pewee is well underway at least by mid-August, a time when some nests are still being initiated (Fig. 43).

An adult wood pewee found dead just south of Illinois in Kentucky was in extensive body molt on August 2, and in Illinois on August 20 we have seen some wood pewees in badly worn plumage and others apparently in fresh plumage. A pewee killed at a tower in central Illinois on the night of September 16-17 was almost through the post-juvenile molt with only a few pin feathers on its head.

Illinois observers usually record the last wood pewees of the fall in late September or October (Fig. 43, DuMont 1947, Blake 1941, Brodkorb 1926*b*, Kleen & Bush 1972*a*), and a pewee at Springfield on November 8, 1972 observed by H. D. Bohlen (Kleen & Bush 1973) was exceptionally late.

Our fall counts of wood pewees seem low (Fig. 43) when we consider that the fall numbers should show the productivity of the preceding nesting season. The ratios of our spring to fall counts were: 1.0 in the spring to 2.0 in the fall (north), 1.0 to 1.0 (central), and 1.5 to 1.0 (south). The low fall counts, which we have seen in other flycatchers also, are perhaps related to the fact that nonsinging fall birds are less conspicuous than the more vociferous spring birds, but we cannot explain the commonly observed pattern of a progressively descending ratio of fall birds from north to south.

Food Habits

The food habits of the eastern wood pewee in Illinois are inadequately known. Three stomachs from pewee specimens collected in Tazewell County and examined by Forbes (1882*a*) contained chiefly unspecified flies and gnats (55 percent of the food) and small beetles (23 percent) plus ants and other Hymenoptera. Rice's (1946) study also shows Diptera to constitute the principal food (35-50 percent of the food), with Hymenoptera (20-25 percent), Coleoptera (10-20 percent), and Lepidoptera (5-15 percent) also important in the diet.

Lyon (1925) once saw a wood pewee steal a butterfly from a woodpecker, but if such pirating behavior is common it has generally escaped detection.

OLIVE-SIDED FLYCATCHER

(Nuttallornis borealis)

(Fig. 46 and 47)

Spring Migration

The olive-sided flycatcher is a regular migrant throughout Illinois in the spring and fall. Its arrival in the spring is usually in early May (Fig. 48). The earliest recorded date for the state is April 29 for central Illinois (Smith 1930). It has been recorded in the St. Louis area on April 30 (Cooke 1888) and May 2 (Anderson 1962). The spring migration of the olive-sided flycatcher regularly extends into June even in southern Illinois (Fig. 48), making it one of the latest spring migrants in the state. The earliest credible record for northern Illinois is May 3 (Smith 1942). The lastest date of occurrence in the spring is June 18 at Deerfield in northern Illinois (Boulton & Pitelka 1938).

Olive-sides often sing in migration even in southern Illinois. The song is a quickly delivered "hic-three-beers." Often they give characteristic "ter, ter, ter" or "pip, pip, pip" calls. We most often have seen olive-sides, singly, perched on dead branches near the tops of tall trees at the edges of clearings.

Fall Migration

This species is among the first northern passerine migrants seen in Illinois in late summer. The olive-sided flycatcher appears in the Chicago area as early as August 9 (Ford 1956). They reach even southern Illinois by the third week in August. There is a July 6 date for northern Illinois (Ford 1956), and Nelson (1876-1877) felt that the species possibly bred in the state because of June records (Fig. 48). However, until nesting is actually observed these June-July records must be regarded as spring stragglers or early "fall" arrivals. The closest known breeding population of olive-sides is in Wisconsin (Fig. 47). Peak numbers in the fall occur in early and mid-September (Fig. 48). Total numbers seen by the authors were slightly more in the fall than in the spring (1.3 to 1.0). The latest date we have for the species is October 5 in southern Illinois (Fig. 48).

In our spring censuses far more birds of this species were seen on the eastern side of the state than on the western side (4.4 to 1.0). In the fall this is also true the ratio is about 2.7 in the east to 1.0 in the Although the olive-sided flycatcher is considered so in its habits, Gault (unpublished notes) often saw together (a pair?) in spring. Once he observed tha such birds were "quarrelsome with each other." I fall several (as many as five) may occasionally be together and may represent family groups. They d generally occur in other bird flocks. The largest nu seen by the authors at any one time was 10 in 2 h September 7, 1957 in central Illinois.

Fig. 46. — Drawing of olive-sided flycatcher. This species is d color, like the wood pewee, but larger and with heavy gray shadi its sides.

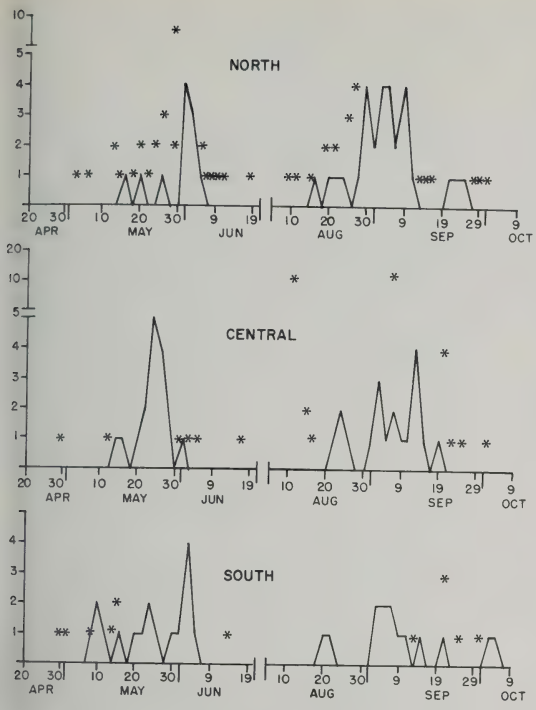
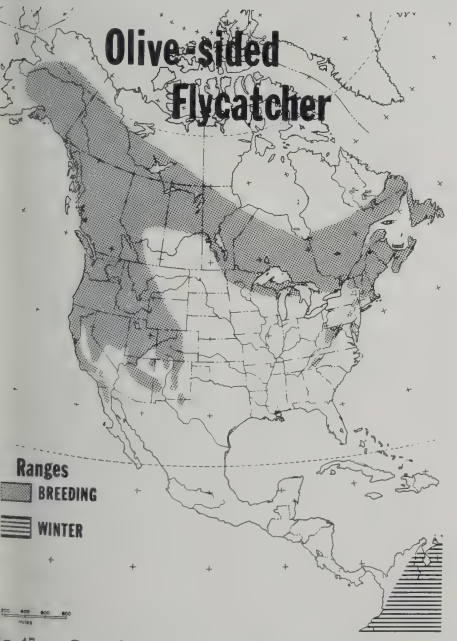


Fig. 48. — Migration seasons of the olive-sided flycatcher in different areas of the state (see Fig. 1). Spring and fall graph lines (1967-1970) show highest daily counts of each 2 days (left scale). Asterisk symbols represent counts made in other years or by other observers.



g. 47. — General distribution of the olive-sided flycatcher. The ied range may include large sections in which populations of the s are thin or even absent because of the nature of the terrain and ty of suitable habitat.

VERMILION FLYCATCHER

(*Pyrocephalus rubinus*)

This colorful species of the far southwestern United States and Central and South America has been found repeatedly in the St. Louis, Missouri area in recent years, both in the spring — April and May (Kleen & Bush 1971*a*, Fawks 1971) and in the fall — September-November (Petersen 1968*a*, Hamilton 1968, Fawks 1968*a*, Anderson & Bauer 1968, Kleen & Bush 1973). As many as four vermilion flycatchers have been seen together, and one male remained from at least September 30 to November 12, 1967 near St. Louis.

In the spring of 1962 we saw an adult male vermilion flycatcher on the University of Illinois campus, Urbana, but our notes on this observation were lost and the date is unknown.

A better-documented record of the species in Illinois was an adult male seen May 4, 1973 at the Chicago Botanic Garden, Glencoe, Illinois by at least eight observers from the Evanston Bird Club, including Mrs. Perry Jones of Winnetka and Mrs. Sidney North of Evanston. The bird was tame, and was observed at length, flycatching. Several of the observers knew the species from observations in its normal range.

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Biology

The Literature of Arthropods Associated with Alfalfa

1. A BIBLIOGRAPHY OF THE SPOTTED ALFALFA APHID

Therioaphis maculata (Buckton) (Homoptera: Aphidae)

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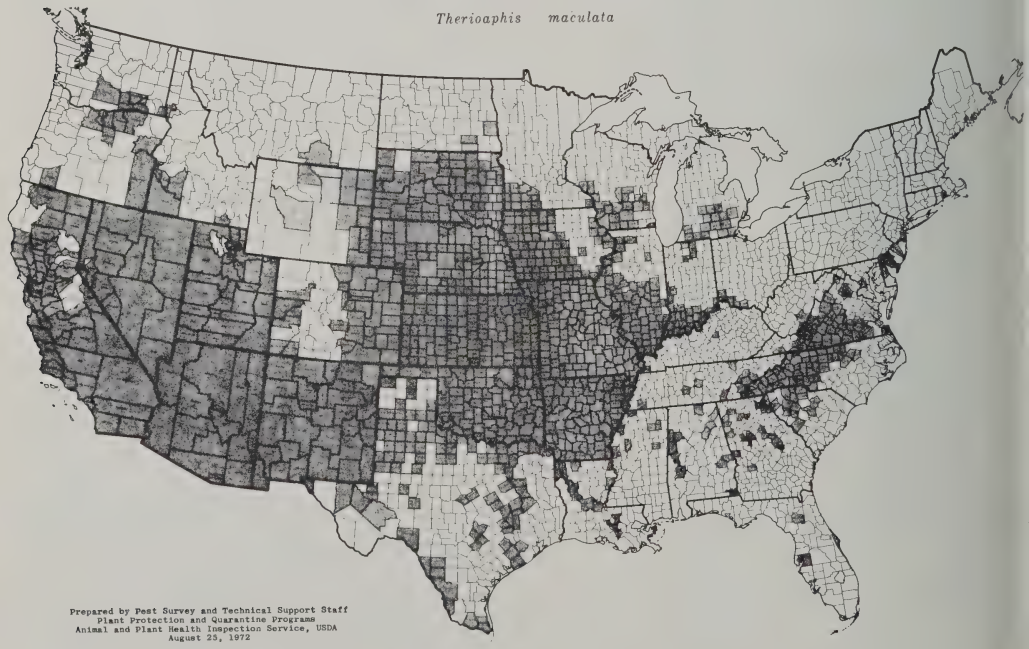
Distribution of Spotted Alfalfa Aphid

Therioaphis maculata



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The Literature of Arthropods Associated with Alfalfa

I. A BIBLIOGRAPHY OF THE SPOTTED ALFALFA APHID

Therioaphis maculata (Buckton) (Homoptera: Aphidae)

D. W. Davis, M. P. Nichols, and E. J. Armbrust

THE ALFALFA ECOSYSTEM is unique among field-crop systems in that it represents a relatively long-lasting, well-established, perennial system that exists nationally over a variety of climatic, geographical, and edaphic conditions. Because of these many subsystems, the interactions with other specific agroecosystems or natural systems are equally as varied. Alfalfa supports a wide variety of insects. These include destructive insects, pollinating insects, species that inhabit the fields because of the lush habitat but have little effect on the crop, and many other associated predators and parasites. Because of the perennial growth habits of alfalfa, many pest and beneficial insect species of other crops overwinter or build up in alfalfa before migrating to neighboring crops systems.

Considerable laboratory and field data dealing with chemical, biological, and cultural methods of controlling alfalfa insects are available. These data need to be closely interpreted with respect to their implications for integrated control and then applied in integrated pest management programs in the field. The breadth and depth of research on alfalfa insect control and alfalfa production in general have been sufficiently productive to implement some programs now.

To facilitate better use of existing literature in developing pest management systems, bibliographies of the key pest species on alfalfa are being prepared in cooperation with the Soybean Insect Research and Information Center (SIRIC) at the Illinois Natural History Survey and University of Illinois. SIRIC has developed a set of computer programs for the IBM/360 at the University of Illinois, which makes possible the retrieval of literature citations associated with a subject or combination of subjects. The bibliographies of the key alfalfa pests, starting with *Therioaphis maculata* have been stored on magnetic tape and are retrievable using the SIRIC system.

Damage from the spotted alfalfa aphid was first recognized in the United States during 1954. When it was first reported, most of the workers believed that it was a form of the yellow clover aphid which had become adapted to alfalfa. Within a couple of years it was found that this was not the case. The spotted alfalfa aphid was apparently a new introduction into the United States from the Near East. The first reports were from New Mexico, but it required only a couple of years for the aphid to spread throughout the southwestern part of the United States. Shortly thereafter it was widely distributed through most of the country. It is still considered essentially a warm-climate insect best adapted to the southern tier of states. It has the ability, however, to spread rapidly on wind currents, so by mid- or late season, it often spreads well into the colder areas of the Rocky Mountains and Midwest.

The spotted alfalfa aphid is much smaller than the pea aphid and can be readily distinguished both by size and color. It is yellowish with dark spots. It also produces much more honeydew and can usually be recognized by the sticky mess. When disturbed, these aphids actively jump from the plants. Summer winged forms are produced in much larger numbers than the pea aphid.

Damage to the alfalfa plant is of several types. The possibility of virus transmission has been discussed by several authors, but has never been verified. Many workers believe that the aphid is capable of producing a toxin which is injected into the alfalfa plants, helping to produce symptoms. Young plants of susceptible varieties can tolerate very few aphids without being killed. The tremendous amounts of honeydew produced have created problems such as clogging of harvesting equipment. Mold growing on this honeydew reduces livestock acceptance of the alfalfa. Stunted plants, poor seed set, and short stand life are typical symptoms.

The spotted alfalfa aphid is a one-host-plant aphid. It has a continuous life cycle on alfalfa and normally does not produce sexual forms in the fall. This means that the best survival of the aphid occurs in areas where there is alfalfa growth during the entire year. The adult aphids often crawl down around the base of the plant where they are capable of surviving during the winter unless the climate is too severe. In cold areas, there may be complete mortality. This is the basic reason that the spotted alfalfa aphid is a problem primarily in warmer climates. Starting about 3 years after its initial introduction into the United States, a few sexual forms were noted during the fall of the year. These sexual forms have never become numerous, but they are a prelude to egg laying on alfalfa stems. There is evidence that the spotted aphid populations in the northern areas, such as South Dakota and Minnesota, have been gradually selecting for larger numbers of these sexual forms. Even with these fall egg-laying aphids, *Medicago* spp.

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remain as the only hosts on which the insect can complete its full cycle. Occasional collections have been made from other legumes. The aphids multiply extremely rapidly during the summer, producing a large number of winged forms. These winged forms are carried by wind currents very readily and have been picked up at high elevations by aircraft. This summer distribution of winged forms can take place over several hundred miles.

Control measures have taken three major pathways. The first and probably most important of these has been the development of resistant alfalfa varieties. The resistant varieties are tolerant to the toxin of as well as the feeding damage by the aphids. Several very successful parasites have been introduced into the United States and unquestionably these have been instrumental in reducing the spotted alfalfa aphid damage in southwestern areas. In addition to the introduction of parasites, quite a number of the native predators also aid in biological control. The third major approach has been with insecticides. Initially, most of the work involved materials like parathion, but more recent chemical control has centered on the systemic insecticides.

An important aspect of the spotted alfalfa aphid biology is the rapidity in which it develops new biotypes or localized forms. These biotypes have developed in response both to insecticides and to overcoming the resistance of alfalfa varieties. In some of the areas, for example in Arizona, the location of these biotypes has been mapped, but in areas further north, which are reinfested by flights from the south, there has been considerable confusion. The aphids, which are blown northward to establish annual populations, do not always originate from the same source; thus the type of insecticidal resistance varies considerably from year to year.

Sources for the entries listed in this bibliography were *Index to the Literature of American Economic Entomology, Review of Applied Entomology, Series A, Science Citation Index, Zoological Record, Agricultural Index,* and references cited in the articles. All entries were examined by workers, either at Utah State University or the University of Illinois, except those preceded by the symbol #. The references are listed alphabetically by author(s) and numbered consecutively. A subject table containing the reference numbers appears on page 13. References are arranged according to subject and period of publication. The table is intended as a quick subject index to the references in the bibliography. More in-depth indexing was done for the SIRIC system, and is available to researchers.

References to *Therioaphis maculata* found in the USDA Cooperative Economic Insect Report, 1954–1972 are included as an appendix following the numbered references. Abbreviations and complete titles of the sources which appear in the bibliographic entries are to be found in a listing at the end of the paper.

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PERIODICAL ABBREVIATIONS

Acta Entomol. Bohemoslov. — Acta Entomologica Bohemoslovaca.
Agr. Chem. — Agricultural Chemicals.
Agr. Tec. Mex. — Agricultura Tecnica en Mexico.
Agron. J. — Agronomy Journal.
American Cyanamid Co. Leafl. — American Cyanamid Company Leaflet.
Ann. Entomol. Soc. Amer. — Annals of the Entomological Society of America.
Ann. Soc. Entomol. Fr. — Annales de la Société Entomologique de France.
Annu. Rev. Entomol. — Annual Review of Entomology.
Ariz. Agr. Exp. Sta. Bull. — Arizona Agricultural Experiment Station Bulletin.
Ariz. Agr. Exp. Sta. Mimeo. Rep. — Arizona Agricultural Experiment Station Mimeographed Report.
Ariz. Coop. Ext. Serv. Agr. Exp. Sta. Bull. — Arizona Cooperative Extension Service and Agricultural Experiment Station Bulletin.
Ariz. Coop. Ext. Serv. Agr. Exp. Sta. Fold. — Arizona Cooperative Extension Service and Agricultural Experiment Station Folder.
Arkansas Farm Res. — Arkansas Farm Research.
Biul. Inst. Ochr. Rosl. — Biuletyn Instytutu Ochrony Roslin.
Boll. Lab. Entomol. Agr. 'Filippo Silvestri' — Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'.
Bull. Brooklyn Entomol. Soc. — Bulletin of the Brooklyn Entomological Society.
Bull. Entomol. Soc. Amer. — Bulletin of the Entomological Society of America.
Calif. Agr. — California Agriculture.
Calif. Agr. Exp. Sta. Ext. Serv. Leafl. — California Agricultural Experiment Station Extension Service Leaflet.
Calif. Agr. Ext. Serv. Iden. Sheet — California Agricultural Extension Service Identification Sheet.
Calif. Agr. Ext. Serv. Manuscript — California Agricultural Extension Service Manuscript.
Calif. Dep. Agr. Quart. Bull. — California Department of Agriculture Quarterly Bulletin.
Can. Entomol. — Canadian Entomologist.
Commonw. Inst. Biol. Contr. Tech. Bull. — Technical Bulletin of the Commonwealth Institute of Biological Control.
Crop Sci. — Crop Science.
Crops Soils Mag. — Crops and Soils Magazine.
Ekol. Pol. Ser. A. — Ekologia Polska-Seria A.
Entomol. Rev. — Entomological Review.
Environ. Entomol. — Environmental Entomology.
Farm Manage. — Farm Management.
Folia Entomol. Mex. — Folia Entomologica Mexicana.
Indian Agr. — Indian Agriculturist.
Indian J. Entomol. — Indian Journal of Entomology.
Israel J. Entomol. — Israel Journal of Entomology.
J. Econ. Entomol. — Journal of Economic Entomology.
J. Environ. Qual. — Journal of Environmental Quality.
J. Insect Physiol. — Journal of Insect Physiology.
J. Kans. Entomol. Soc. — Journal of the Kansas Entomological Society.
Kans. Agr. Exp. Sta. Mimeo. Ser. — Kansas Agricultural Experiment Station Mimeograph Series.
Kans. Agr. Exp. Sta. Tech. Bull. — Kansas Agricultural Experiment Station Technical Bulletin.
Mex. Secr. Agr. Ganad. Ofic. Estud. Espec. Foll. Tec. — Mexico Secretaria de Agricultura y Ganaderia, Oficina de Estudios Especiales, Folleto Tecnico.
Misc. Publ. Entomol. Soc. Amer. — Miscellaneous Publications of the Entomological Society of America.
Miss. Agr. Forest. Exp. Sta. Annu. Rep. — Mississippi Agricultural and Forestry Experiment Station Annual Report.
Mitt. Biol. Bundesanst. Land- Forstwirtsch. Berlin-Dahlem — Mitteilungen aus der biologischen Bundesanstalt fuer Land- und Forstwirtschaft Berlin-Dahlem.
Mont. State Univ. Coop. Ext. Serv. Leafl. — Montana State University Cooperative Extension Service Leaflet.
N. Mex. Agr. Exp. Sta. Bull. — New Mexico Agricultural Experiment Station Bulletin.
Nebr. Agr. Exp. Sta. Bull. — Nebraska Agricultural Experiment Station Bulletin.
Nebr. Agr. Exp. Sta. Res. Bull. — Nebraska Agricultural Experiment Station Research Bulletin.
Nev. Agr. Exp. Sta. Circ. — Nevada Agricultural Experiment Station Circular.
Okla. Agr. Exp. Sta. Bull. — Oklahoma Agricultural Experiment Station Bulletin.
Okla. Agr. Exp. Sta. Processed Ser. — Oklahoma Agricultural Experiment Station Processed Series.
Pr. Nauk. Inst. Ochr. Rosl. — Prace Naukowe Instytutu Ochrony Roslin.
Probl. Agr. — Probleme Agricole.
Proc. 10th Int. Congr. Entomol. (Montreal) — Proceedings of the 10th International Congress of Entomology (Montreal)
Proc. 12th Int. Congr. Entomol. (London) — Proceedings of the 12th International Congress of Entomology (London)
Proc. Forage Insect Res. Conf. — Proceedings of the Forage Insect Research Conference.
Proc. Indiana Acad. Sci. — Proceedings of the Indiana Academy of Science.
Proc. N. Cent. Br. Entomol. Soc. Amer. — Proceedings of the North Central Branch, Entomological Society of America
Progr. Agr. Ariz. — Progressive Agriculture in Arizona.
Rep. Alfalfa Impr. Conf. — Report of the Alfalfa Improvement Conference.
S. Dak. State Univ. Coop. Ext. Serv. Handb. — South Dakota State University Cooperative Extension Service Handbook
S. Pasture Forage Crop Improv. Conf. Rep. — Southern Pasture and Forage Crop Improvement Conference Report.
Tex. Agr. Exp. Sta. Progr. Rep. — Texas Agricultural Experiment Station Progress Report.
U.S. Dep. Agr. Agr. Handb. — United States Department of Agriculture, Agriculture Handbook.
U.S. Dep. Agr. Agr. Res. Serv. Prod. Res. Rep. — United States Department of Agriculture, Agricultural Research Service Production Research Report.
U.S. Dep. Agr. ARS 22- — United States Department of Agriculture, Agricultural Research Service #22 Series.
U.S. Dep. Agr. ARS 33- — United States Department of Agriculture, Agricultural Research Service #33 Series.
U.S. Dep. Agr. Leafl. — United States Department of Agriculture Leaflet.
Univ. Calif. Publ. Entomol. — University of California Publications in Entomology.
Univ. Mo. Coop. Ext. Serv. Handb. — University of Missouri Cooperative Extension Service Handbook.
Utah Agr. Exp. Sta. Mimeo. Ser. — Utah Agricultural Experiment Station Mimeograph Series.
Utah Agr. Ext. Serv. Entomol. Mimeo Ser. — Utah Agricultural Extension Service, Entomology Mimeo Series.
Utah Agr. Ext. Serv. Leafl. — Utah Agricultural Extension Service Leaflet.
Utah Agr. Ext. Serv. Mimeo. Ser. — Utah Agricultural Extension Service Mimeograph Series.
Utah Ext. Leafl. — Utah Extension Leaflet.
Va. Agr. Exp. Sta. Tech. Bull. — Virginia Agricultural Experiment Station Technical Bulletin.
Va. Polytech. Inst. Ext. Div. Contr. Ser. — Virginia Polytechnic Institute Extension Division Control Series.
Zool. Listy — Zoologické Listy.
Zool. Verh. Rijksmus. Natuur. Hist. Leiden — Zoologische Verhandelingen Rijksmuseum van Natuurlijke Historie Leiden

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e Literature of Arthropods Associated with Alfalfa

A BIBLIOGRAPHY OF THE

TONA SPECIES

oleoptera: Curculionidae)

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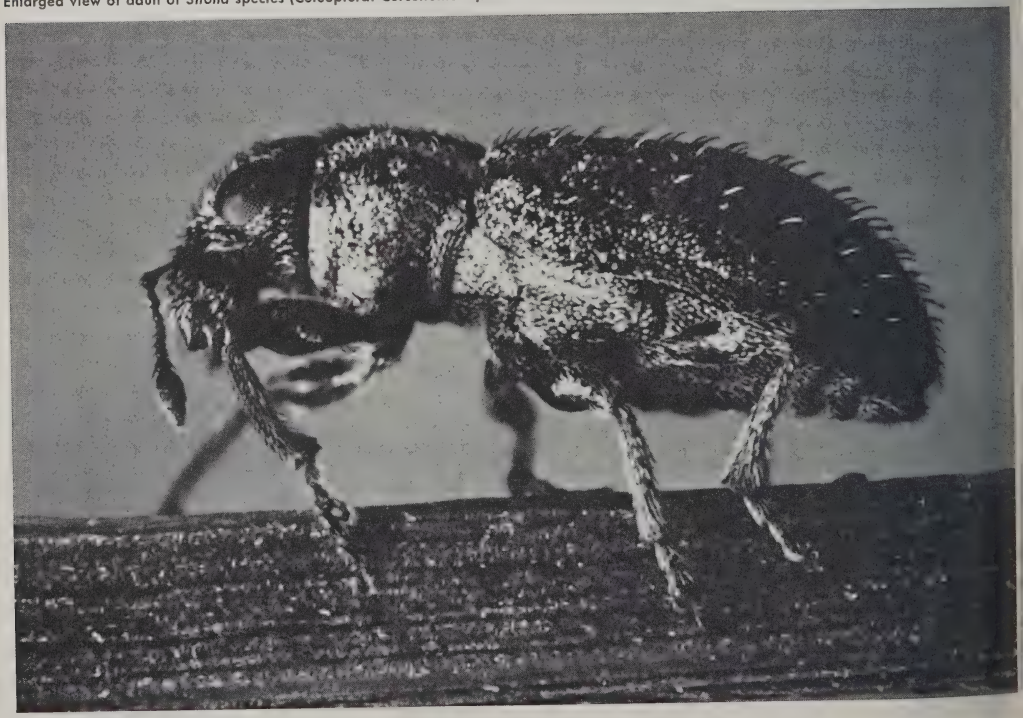
Enlarged view of adult of *Sitona* species (Coleoptera: Curculionidae).



The Literature of Arthropods Associated with Alfalfa

II. A BIBLIOGRAPHY OF THE *SITONA* SPECIES (Coleoptera: Curculionidae)

W. P. Morrison, B. C. Pass,
M. P. Nichols, and E. J. Armbrust

THE ALFALFA ECOSYSTEM is unique among field-crop ystems in that it represents a relatively long-lasting, well-stablished perennial system that exists nationally over a ariety of climatic, geographical, and edaphic conditions. ecause of the many subsystems, the interactions with ther specific agroecosystems or natural systems are qually as varied. Alfalfa supports a wide variety of in-ects. These include destructive insects, pollinating insects, ecies that inhabit the fields because of the lush habitat ut have little effect on the crop, and many associated redators and parasites. Because of the perennial growth abits of alfalfa, many pest and beneficial insect species f other crops overwinter or build up in alfalfa before igrating to neighboring crops systems.

Considerable laboratory and field data dealing with emical, biological, and cultural methods of control of lfalfa insects are available. These data need to be closely terpreted with respect to their implications for inte-rated control and then applied in integrated pest man-gement programs in the field. The breadth and depth f research on alfalfa insect control and alfalfa produc-on in general have been sufficiently productive to imple-ent some programs now.

To facilitate use of existing literature in developing est management systems, bibliographies of the key pest ecies on alfalfa are being prepared for use by research-s. This bibliography on *Sitona* species (Coleoptera: urculionidae) is the second in a series concerning lfalfa insects of economic importance. This and subse-ent bibliographies of arthropods associated with alfalfa e part of an information storage and retrieval system ing compiled as one objective of the US/IBP project titled "The Principles, Strategies, and Tactics of Pest anagement Regulation and Control in the Alfalfa Eco-stem." This information system utilizes existing facilities d methodology employed by the University of Illinois ybean Insect Research and Information Center. SIRIC s developed a set of computer programs for the IBM/ 0 at the University of Illinois which makes possible e retrieval of literature citations associated with a sub-ct or combination of subjects. The bibliographies of e key alfalfa pests, starting with *Therioaphis maculata* ve been stored on magnetic tape and are retrievable ing the SIRIC system.

The genus *Sitona* includes a large number of species, any of which are known to be injurious to leguminous ps (Wildermuth 1910).[1] In general, the larvae are root feeders, whereas adults attack the foliage. Arnett (1962)[2] reports 17 species of *Sitona* as occurring in the United States. Several species have been introduced into North America from Europe and are now pests on both continents. The crops most commonly attacked are clover, alfalfa, peas, beans, and vetch. The pest species include: *S. lineata* (pea leaf weevil), *S. cylindricollis* (sweetclover weevil), *S. hispidula* (clover root curculio), *S. scissifrons* (lesser alfalfa weevil), and *S. flavescens* (yellow clover curculio).

The clover root curculios eat small crescent-shaped notches on the edges of alfalfa and clover leaves. The larvae feed on the roots, pitting and scarring the surface. They may also burrow into the root, but they do not hollow out the center as the clover root borer does. If feeding is severe, the root may be almost girdled and the plant may die during warm, dry weather. The curculios feed primarily at night and are seldom found on the plants during the day.

Clover root curculios winter mainly as larvae, but a few may spend the winter as adults or eggs. Wintering larvae feed on the roots in early spring and emerge in the spring. The adults feed for a time in the late spring, become inactive during the summer, and feed again in the fall. They lay eggs throughout the fall, often as late as mid-November. Eggs laid late in the season overwinter, but those laid earlier hatch and the larvae overwinter. If all eggs are not deposited in the fall, the adult overwinters and completes egg-laying in the spring. The sweetclover weevil hibernates in ground debris in and around sweet clover fields. With the first warm weather, it begins to feed on the plants, notching the leaves noticeably. The females lay eggs in the spring. The young grub-like larvae feed in clover soils in late May, June, and July. They pupate in late June and July, emerging as adults in July and August. The adults feed moderately in the fall prior to winter hibernation.

The weevils feed on the larvae of sweet clover plants, retarding the spring growth of established stands. Only in rare instances are established stands killed, but weevils will often consume an entire new seeding or seriously

[1] See reference number 570 in the following bibliography.

[2] See reference number 50 in the following bibliography.

This paper, in the Biological Notes series, is published with special project funds. Dr. W. P. Morrison is a Post Doctoral Fellow and Dr. B. C. Pass a Professor of Entomology at the University of Kentucky. M. P. Nichols is a Research Associate, International Programs and Studies, University of Illinois. Dr. E. J. Armbrust is an Associate Entomologist at the Illinois Natural History Survey and Associate Professor of Agricultural Entomology, Illinois Agricultural Experiment Station.

reduce the stand. The damage is most noticeable in thin stands, but may also occur in heavy stands.

The following reference sources were used to compile the bibliography: *Review of Applied Entomology, Biological Abstracts, USDA Bibliography of Agriculture, Agricultural Index,* and footnotes and literature cited in the references themselves. The bibliography includes all references occurring in these sources and is as complete as possible. There has been no screening of references and therefore, considering the European origin of most pest species, the bibliography includes numerous European publications.

All articles which were in the University of Kentucky and University of Illinois libraries were read and indexed from the publications themselves. Articles which were not available in the libraries or on inter-library loan were indexed from the published abstract or title. These articles which have not been seen are designated by the symbol #. The references are listed alphabetically by author(s) and numbered consecutively. A subject grid table containing the reference numbers appears following the numbered references. References are arranged according to subject and period of publication. The table is intended as a quick subject index to the references in the bibliography. More in-depth indexing was done for the SIRIC system.

Abbreviations and complete titles of the sources which appear in the bibliographic entries are presented in a listing at the end of the paper. References to most reports in the USDA *Cooperative Economic Insect Report,* USDA *Insect Pest Survey Bulletin,* and *Canadian Insect Pest Review* have not been included.

Mr. Ray Kotek worked in the organization of the files and provided general technical assistance, and O. F. Glissendorf edited the manuscript. Their collaboration is gratefully acknowledged.

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#590. Zolk, K. 1932. Einiges über die Tätigkeit der Versuchsstation für angew. Entomologie d. Universität Tartu 1921-1932. [A few notes on the activities of the Experiment Station for Applied Entomology of the Tartu (Dorpat) University in the years 1921–1932.] (In Estonian) Mitt. Versuchssta. Angew. Entomol. Univ. Tartu 21. 10 p. maps.

#591. Zolotarevsky, B. N. 1915. Preliminary report on the work on entomology in 1914. (In Russian) Stavropol-Caucasian Agr. Exp. Sta. Stavropol Munic. Auth. 12 p.

ADDENDUM

592. Beland, G. L., F. A. Haskins, G. R. Manglitz, and H. J. Gorz. 1973. Sweetclover weevil: Adenosine as a feeding stimulant. J. Econ. Entomol. 66(5):1037-1039. illus. refs.

PERIODICAL ABBREVIATIONS

Acta Zool. Cracov. — Acta Zoologica Cracoviensia.
Agr. Chem. — Agricultural Chemicals.
Agr. Gaz. N. S. W. — Agricultural Gazette of New South Wales.
Agr. Impr. Meas. Zemstvo Govt. Ufa — Agricultural Improvement Measures of the Zemstvo of the Government of Ufa.
Agr. Sarda — (Exact source unknown).
Agron. Dep. Zemstvo Govt. Ufa — Agronomical Department of the Zemstvo of the Government of Ufa.
Agron. Lusitana — Agronomia Lusitana.
Amer. Bee J. — American Bee Journal.
Ann. Appl. Biol. — Annals of Applied Biology.
Ann. Entomol. Fenn. — Annales Entomologici Fennici.
Ann. Entomol. Soc. Amer. — Annals of the Entomological Society of America.
Ann. Inst. Phytopathol. Benaki — Annales de l'Institut Phytopathologique Benaki.
Ann. Soc. Entomol. Fr. — Annales de la Société Entomologique de France.
Ann. Univ. Mariae Curie-Sklodowska Sect. C Biol. — Annales Universitatis. Mariae Curie-Sklodowska Sectio C Biologia.
Ann. Serv. Épiphyt. — Annales du Service des Épiphyties.
Annu. Rev. Entomol. — Annual Review of Entomology.
Anz. Schädlingsk. — Anzeiger für Schädlingskunde.
Aquila — Aquila A Madártani Intézet Évkönyve.
Aust. J. Sci. — Australian Journal of Science.
Beitr. Entomol. — Beiträge zur Entomologie.
Ber. Deut. Pharm. Ges. — Berichte der Deutschen Pharmazeutischen Gesselschaft.
Beretn. Statens Forsøksvirks. PlKult. — Beretning fra Statens Forsøksvirksomhed i Plantekultur.
Biol. Zentralbl. — Biologisches Zentralblatt.
Bitki Koruma Bült. — Bitki Koruma Bülteni.
Boll. Ist. Entomol. Univ. Studi Bologna — Bollettino dell'Instituto di Entomologia della Università degli Studi di Bologna.
Boll. Lab. Entomol. Agr. 'Filippo Silvestri' — Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'.
Boll. Lab. Zool. Gen. Agr. R. Scuola Super. Agr. Portici — Bollettino del Laboratorio di Zoologia Generale e Agraria della R. Scuola Superiore d'Agricoltura, Portici.
Boll. Soc. Entomol. Ital. — Bollettino della Societa Entomologica Italiana.
Brit. Columbia Dep. Agr. Publ. — British Columbia Department of Agriculture Publication.
Brit. Grassl. Soc. J. — British Grasslands Society Journal.
Bull. Ecol. Super. Agr. Tunis — Bulletin École Superieure d'Agriculture Tunis.
Bull. Entomol. Dep. Nikolaevsk Exp. Sta. — Bulletin of the Entomology Department of Nikolaevsk Experiment Station.
Bull. Entomol. Res. — Bulletin of Entomological Research.
Bull. Hort. (Liège) — Bulletin Horticole (Liège).
Bull. Inst. Rech. Biol. Sta. Biol. Univ. Perm. — Bulletin de l'Institut de Recherches Biologiques et de la Station Biologique à l'Université de Permskom.
Bull. Moscow Entomol. Soc. (Soc. Entomol. Mosquensis) — Bulletin of the Moscow Entomological Society (Societa Entomologica Mosquensis).
Bull. Moskovsk. S-Kh. Obl. Op. Stantz. Polevod. — (Exact source unknown).
Bull. Pests Agr. Meth. Control. — Bulletins on Pests of Agriculture and Methods of Controlling Them (Charkov).
Bull. Plant Prot. (Leningrad) — Bulletin of Plant Protection (Leningrad).
Bull. Soc. Entomol. Fr. — Bulletin de la Société Entomologique de France.
Bull. Soc. Ouralienne Amis Sci. Natur. — Bulletin de la Société Ouralienne d'Amis des Sciences Naturelles.
Bull. Soc. Pathol. Veg. Fr. — Bulletin de la Société de Pathologie Vegetale de France.
Bull. Soc. Sci. Natur. Phys. Maroc — Bulletin de la Société des Sciences Naturelles et Physiques du Maroc.
Bull. Soc. Sci. Natur. Tunisie — Bulletin de la Société des Sciences Naturelles du Tunisie.
Bull. Tiflis-Erivan-Kars Bur. Control Pests Agr. — Bulletins of the Tiflis-Erivan-Kars Bureau for the Control of Pests of Agriculture (Tiflis).
Bull. Univ. Tehran Agr. Coll. — Bulletin, University of Tehran Agricultural College.
Calif. Dep. Agr. Bull. — California Department of Agriculture Bulletin.
Calif. Dep. Agr. Spec. Publ. — California Department of Agriculture Special Publication.
Calif. State Comm. Hort. Mon. Bull. — California State Commission of Horticulture Monthly Bulletin.
Can. Dep. Agr. Div. Entomol. Processed Publ. — Canada Department of Agriculture, Division of Entomology Processed Publication.
Can. Dep. Agr. Publ. — Canada Department of Agriculture Publication.
Can. Entomol. — Canadian Entomologist.
Can. Exp. Farms Serv. West. Forage Crops Comm. Rep. — Canadian Experimental Farms Service, Western Forage Crops Committee Report.
Can. Field Natur. — Canadian Field Naturalist.
Can. Insect Pest Rev. — Canadian Insect Pest Review.
Can. J. Agr. Sci. — Canadian Journal of Agricultural Science.
Can. J. Bot. — Canadian Journal of Botany.
Can. J. Plant Sci. — Canadian Journal of Plant Science.

TABLE OF REFERENCES BY SUBJECT AND PERIOD OF PUBLICATION

SUBJECT \ YEAR	Prior to 1900	1900 1909	1910's	1920's	1930's	1940's	1950's	1960's	1970's
TAXONOMY	27,454		74,121,570	177,212,234	38,46,73,292	276,389,390	213,215,216,217, 248,293,308,448, 476,481,536	28,50,94,149,249, 250,251,356,398, 418,482,523	151,192
BEHAVIOR			566	529	39,43,45,435	135	98,317,515,516, 528	15,90,91,92,104, 187,188,311,320, 335,419,491,517	22,106,130, 513
LIFE HISTORY & BIOLOGY		142	78,121,171,246, 353,404,566,570	4,219,223,225, 229,230,239,266, 267,505,530,561, 581	37,38,39,40,43, 45,46,47,58,63, 83,112,160,282, 321,339,394,411, 443,456,522,527, 580,582	25,66,67,68,84, 85,135,303,369, 378,380,412,479, 576	69,70,132,145,175, 185,186,193,196, 200,202,203,317, 323,324,341,358, 384,441,462,463, 474,528,553,587	90,92,103,105,119, 174,179,252,258, 322,330,343,344, 345,346,360,361, 362,401,402,415, 420,432,490,491, 509,512,588	106,153,347, 365,403,460
ECOLOGY				223,336,529	37,45,278,394, 411,435,456,522		462,463,553,587	105,188,258,281, 315,318,401,402, 413,414,419,420, 490,491,563	130,365
DISTRIBUTION	472		54,72,100,138, 139,164,165,245, 260,264,270,316, 350,352	76,77,97,110, 140,141,150,169, 170,209,224,225, 236,243,305	73,82,89,112, 125 221,235,268, 274,278,283,292, 294,354,363,395, 434	66,87,88,115, 136,148,152,158, 220,325,333,349 367,379	69,124,128,154, 155,163,178,194, 204,256,306	14,28,29,30,50,94, 119,120,127,137, 143,174,184,238, 330,357,359,386, 388,510,546	151
PHYSIOLOGY & MORPHOLOGY			171,566,570	225,228,229	39,41,42,43, 44,46,47,231, 233,387		108,215,216,462, 553	16,17,19,20,21,23, 26,91,187,188,319, 320,361,418,523	18,22,106, 151,153,162, 592
TRAPPING & SAMPLING					75				
ECONOMIC ROLE & DAMAGE	565	142	1,72,111,164, 264,269,289,290, 291,304,351,399, 400,404,405,416, 436,437,439,451, 452,461,465,466, 480,485,520,521, 534,535,540,541, 544,555,557,558, 567,583,591	2,3,5,76,99,209, 210,223,225,226, 236,239,243,255, 263,266,267,305, 327,348,381,431, 440,455,467,537, 545,554,559,560, 571,572,579,585	38,39,46,58,82, 89,96,112,211 221,237,261,272, 273,274,282,283, 294,321,332,354, 383,394,410,443, 469,488,489,492 493,506,533,538, 539,569,580	13,25,53,66,67, 87,148,242,277, 285,303,325,333, 337,338,355,364, 369,370,379,396, 409,412,449 459, 478,486,501,525, 568,589	31,32,33,48,59,64, 107,109,124,132, 134,167,175,193, 206,214,244,247, 254,256,262,279, 287,288,323,328, 341,374,391,421, 438,474,477,487, 499,502,510,514, 543,548,549,551, 552	49,51,80,102,104, 118,120,155,157, 168,174,179,208, 222,259,265,311, 330,331,343,344, 345,346,357,385, 386,401,402,413, 414,415,420,423, 424,427,429,432, 453,496,497,511, 512,547,562,586	129,207,347, 433
PARASITES, PREDATORS, & DISEASE			240,271,566,570	225,227,241	40,232,334,527	35,36,66,371, 372,375,376,377, 500,504	61,65,69,131,373, 393,463	14,102,253,295, 296,297,298,299, 300,301,302,362, 426	
NON-INSECTICIDAL CONTROL METHODS			62,246,289,353, 566,570	6,101,430	272,339,411,435, 527,580,582	66,68,71,84,158, 309,340,368,369, 375,377,378,380, 397,409,412,503	31,32,69,70,132, 358,382,442,575	16,17,19,23,26, 180,257,258,312, 313,415,490,491, 550,588	18,20,21,22
INSECTICIDAL CONTROL METHODS			123,444,445,447, 464,542,584	366	40,58,112,122, 160,272,282,284, 410,527,580,590	68,84,93,95,113, 135,190,191,303, 309,340,372,380, 417,450,468,475, 495,503,507,508, 576	7,8,9,10,11,31,32, 33,34,60,70,79,116, 117,132,145,146, 147,172,175,181, 182,183,189,194, 195,196,201,203, 247,275,286,287, 288,307,324,326, 341,342,446,470, 471,474,498,524, 528,556,564,573, 574,575,578	12,24,114,126,133, 144,161,173,174, 179,205,252,265, 280,281,322,329, 343,344,345,346, 392,406,407,408, 415,457,458,473, 483,484,490,491, 494,526,531,532, 563	129,347,460
PLANT RESISTANCE						86,159,380,503	64,98,200,218,518, 577	15,166,176,197, 198,199,310,314, 422,423,424,425	57,519,592
HOST PLANTS			52,81,139,165, 291,570	55,97,99,101, 110,141,169,225, 266,336,428,561	38,46,58,89,112, 125,160,506,527, 569	66,152,325,337, 478	132,317,441,515, 516	49,51,80,104,137, 184,314,331,358, 360,432	403,513
DISEASE TRANSMISSION							56,107		

Can. J. Zool. — Canadian Journal of Zoology.
Čas. Česk. Společnosti Entomol. — Časopis Československé Společnosti Entomologické.
Cent. Agr. Soc. Riga (Wenden) — Central Agricultural Society of Riga (Wenden).
Centralanst. Jorkbruksf. — Centralanstalten för Jordbruksförsök.
Chem. Trade J. — Chemical Trade Journal.
Chor. Szkodn. Rośl. — Choroby i Szkodniki Roślin.
Coleopt. Bull. — Coleopterists' Bulletin.
Columbia Port Dig. — Columbia Port Digest.
Crop Sci. — Crop Science.
Crops Soils Mag. — Crops and Soils Magazine.
Cyprus Agr. J. — Cyprus Agricultural Journal.
Dairy Top. — Dairy Topics.
Déf. Plantes — Défense des Plantes.
Dep. Agr. Cent. Bd. Land Admin. Agr. (Petrograd) — Department of Agriculture of the Central Board of Land Administration and Agriculture (Petrograd).
Deut. Entomol. Z. (n.s.) — Deutsche Entomologische Zeitschrift (New series).
Diss. Giessen — Dissertation Giessen.
Diss. Göttinger — Dissertation Göttinger.
Diss. Math.-Nat. Fakult. Leipzig — (Exact source unknown).
Dokl. Akad. Nauk SSSR — Dokladў Akademii Nauk SSSR.
Dokl. Akad. Nauk Uzb. SSR — Dokladў Akademii Nauk Uzbekskoĭ SSR.
Dokl. Mosk. Sel'sko-khoz. Akad. Imeni K. A. Timiryazeva — Dokladў Moskovskoĭ Sel'sko-khozyaĭstvennoĭ Akademii Imeni K. A. Timiryazeva.
Dokl. Vses. Akad. Sel'sko-khoz. Nauk Imeni V. I. Lenina — Dokladў Vsesoyuznoĭ Akademii Sel'sko-khozaĭstvennўkh Nauk Imeni V. I. Lenina.
East Malling Res. Sta. Annu. Rep. — East Malling Research Station Annual Report.
Empire J. Exp. Agr. — Empire Journal of Experimental Agriculture.
Entomol. Avd. — Entomologiska Avdelningen (Stockholm).
Entomol. Blätter — Entomologische Blätter.
Entomol. Bur. Govt. Zemstvo Poltava — Entomological Bureau of the Government of the Zemstvo of Poltava.
Entomol. Exp. Appl. — Entomologia Experimentalis et Applicata.
Entomol. Mon. Mag. — Entomologist's Monthly Magazine.
Entomol. Nachr. — Entomologische Nachrichten.
Entomol. Obozrenie — Entomologicheskoe Obozrenie (Revue d'Entomologie de l'URSS).
Entomol. Soc. Ont. Annu. Rep. — Entomological Society of Ontario Annual Report.
Entomol. Tidskr. — Entomologisk Tidskrift.
FAO Plant Prot. Bull. — FAO (Food and Agriculture Organization of the United Nations) Plant Protection Bulletin.
FCI Mimeo. — (Exact source unknown).
Farm Home Sci. — Farm and Home Science (Utah).
Farmer Stock-Breed. — The Farmer and Stock-Breeder.
Faune Fr. — Faune de France.
Festschr. Appel — Festschrift Appel.
Flugbl. Abt. Pflanzenkr. K. Wilhelm-Inst. Landwirt. Bromberg — Flugblatt Abteilung für Pflanzenkrankheiten d. Kaiser Wilhelm-Instituts für Landwirtschaft in Bromberg.
Gard. Chron. (Ser. 3) — Gardeners' Chronicle (Series 3).
Gesunde Pflanz. — Gesunde Pflanzen.
Gleanings Bee Cult. — Gleanings in Bee Culture.
Grain Prod. J. — Grain Production Journal.
Gt. Brit. Min. Agr. Fish. Adv. Leafl. — Great Britain Ministry of Agriculture and Fisheries Advisory Leaflet.
Gt. Brit. Min. Agr. Fish. Food Adv. Leafl. — Great Britain Ministry of Agriculture, Fisheries, and Food Advisory Leaflet.
Höfchen-Br. Bayer Pflanzenschutz-Nachr. — Höfchen-Briefe, Bayer Pflanzenschutz-Nachrichten.
Hort. Market-Gard. — Horticulture and the Market-Gardener.
Ill. Agr. Coll. Ext. (Processed) — Illinois Agricultural College Extension (Processed).
Ill. Agr. Exp. Sta. Bull. — Illinois Agricultural Experiment Station Bulletin.
Ill. State Beekeep. Assoc. Annu. Rep. — Illinois State Beekeepers' Association Annual Report.
Inaug.-Diss. Bonn Würzburg — Inaugural-Dissertation, Bonn, Würzburg.
Ind. Saccar. Ital. — Industria Saccarifera Italiana.
Indiana Agr. Exp. Sta. Circ. — Indiana Agricultural Experiment Station Circular.
Insect Pest Surv. Bull. — Insect Pest Survey Bulletin (USDA).
Inst. Agron. "Dr. Petru Groza" Cluj Lucr. Stiint. Ser. Agr. — Institutul Agronomic "Dr. Petru Groza," Cluj, Lucrari Stiintifice, Seria Agricultura.
Iowa Farm Sci. — Iowa Farm Science.
Irrig. Farmer — Irrigation Farmer.
Israel J. Entomol. — Israel Journal of Entomology.
Izdat. Bŭlgar. Akad. Nauk. for Inst. Zasht. Rast. Kostinbrod. (Sofia) — (Exact source unknown).
Izdat. FAN Uzbek. SSR for Sredneaz. Inst. Zashch. Rast. (Tashkent) — (Exact source unknown).
Izv. S'b. Kraev. Stantz. Zashch. Rast. — Izvestiya Sibirskogo Kraevoi Stantzii Zashchity Rastenii (Tomsk).
Izv. Uzb. Fil. Akad. Nauk SSSR — Izvestiya Uzbekistanskogo Filiala, Akademiya Nauk SSSR.
J. Agr. S. Aust. — Journal of Agriculture, South Australia.
J. Anim. Ecol. — Journal of Animal Ecology.
J. Econ. Entomol. — Journal of Economic Entomology.
J. Minn. Acad. Sci. — Journal of the Minnesota Academy of Science.
J. Roy. Agr. Soc. Engl. — Journal of the Royal Agricultural Society of England.
J. Soc. Brit. Entomol. — Journal of the Society for British Entomology.
J. Southeast. Agr. Coll. Wye — Journal of the South-Eastern Agricultural College, Wye, Kent.
Kans. Agr. Exp. Sta. Dir. Rep. — Kansas Agricultural Experiment Station Director's Report.
Kans. State Agr. Coll. Ext. Bull. — Kansas State Agricultural College Extension Bulletin.
Kans. State Bd. Agr. Bien. Rep. — Kansas State Board of Agriculture Biennial Report.
Karteikurzber. Landwirt. — Karteikurzberichte fur die Landwirtschaft.
Kertész. Szölész. Föisk. Évk. — Kertészeti és Szölészeti Föiskola Évkönyve.
Kiiv'ska Kraiova S.-G. Dosl. Statz., Vidd. Entomol. [Kiev Reg. Agr. Exp. Sta., Dep. Entomol.] — (Exact source unknown).
Kísérl. Kozl. — Kísérletügyi Közlemények (Budapest).
Kolkhoz. Proizvod. — Kolkhoznoe Proizvodstvo.
Ky. Agr. Exp. Sta. Circ. — Kentucky Agricultural Experiment Station Circular.
Landbvoorlichtingsdienst. Landbvoorlichting. — (Exact source unknown).
Landesb. Sachsen-Anhalt Wbl. — Landesbauernschaft Sachsen-Anhalt Wochenblatt.
Landwirt. Jahrb. — Landwirtschaftliches Jahrbuch.
Landwirt. Jahrb. Schweiz — Landwirtschaftliches Jahrbuch der Schweiz.
Landwirt. Wschr. Halle — Landwirtschaftliche Wochenschrift Halle.
Latvian Cent. Agr. Soc. — Latvian Central Agricultural Society.
Lauksaimn. Mēnešrak. [J. Agr.] — Lauksaimniecības Mēneša raksts [Journal of Agriculture].
Lenin Acad. Agr. Sci. Leningrad — Lenin Academy of Agricultural Science, Leningrad.
Liet. TSR Mokslu Akad. Darb. Ser. C — Lietuvos TSR Mokslu Akademijos Darbai Serija C.
Lucr. Stiint. Inst. Agron. 'N. Balcescu' Bucuresti Ser. A — Lucrari Stiintifice ale Institutului Agronomie 'N. Balcescu' Bucuresti Series A.
Magy. Mezogazdasag — Magyar Mezogazdasag.
Manitoba Agron. Annu. Conf. — Manitoba Agronomy Annual Conference.

Manitoba Co-op. — (Exact source unknown).
Md. Agr. Exp. Sta. Bull. — Maryland Agricultural Experiment Station Bulletin.
Md. State Hort. Soc. Annu. Rep. — Maryland State Horticultural Society Annual Report.
Medd. Centralanst. Jorsbruksf. — Meddelande fran Centralanstalt för Jorsbruksförök.
Meded. Landbouwhoogesch. Wageningen — Mededeelingen van de Landbouwhoogeschool te Wageningen.
Meded. Proefsta. Akker- Weideb. — Mededelingen Proefstation voor de Akker- en Weidebouw Wageningen.
Meded. Rijks Hoogere Land- tuin- Boschbouwsch. — Mededelingen van de Rijks Hoogere Land-, Tuin- en Boschbouwschool.
Mem. Bur. Entomol. Sci. Comm. Min. Agr. (Petrograd) — Memoirs of the Bureau of Entomology of the Scientific Committee of the Ministry of Agriculture (Petrograd).
Mem. Inst. Nat. Polonais Econ. Rur. Pulawy — Memoires de l'Institut National Polonais d'Economie Rurale à Pulawy.
Mich. Agr. Exp. Sta. Quart. Bull. — Michigan Agricultural Experiment Station Quarterly Bulletin.
Mich. Agr. Exp. Sta. Tech. Bull. — Michigan Agricultural Experiment Station Technical Bulletin.
Mich. State Bd. Agr. Annu. Rep. — Michigan State Board of Agriculture Annual Report.
Minn. Agr. Exp. Sta. Tech. Bull. — Minnesota Agricultural Experiment Station Technical Bulletin.
Minn. Agr. Ext. Serv. Ext. Fold. — Minnesota Agricultural Extension Service Extension Folder.
Minn. Farm Home Sci. — Minnesota Farm and Home Science.
Minn. Sci. — Minnesota Science.
Misc. Publ. Bd. Agr. Fish. Intell. Dep. Plant Dis. Br. London — Miscellaneous Publications, Board of Agriculture and Fisheries, Intelligence Department, Plant Disease Branch, London.
Misc. Publ. Bd. Agr. Fish. London — Miscellaneous Publications, Board of Agriculture and Fisheries, London.
Misc. Publ. Min. Agr. Fish. London — Miscellaneous Publications, Ministry of Agriculture and Fisheries, London.
Misc. Zool. — Miscelánea Zoológica.
Mitt. Biol. Reichsanst. Land- Forstwirt. — Mitteilungen der Biologischen Reichsanstalt für Land- und Forstwirtschaft.
Mitt. Landwirt.-Bakter. Pflanzenschtzsta. Vienna — Mitteilungen Landwirtschaftlich-Bakteriologisch und Pflanzenschutzstation Vienna.
Mitt. Schweiz. Landwirt. — Mitteilungen für die Schweizerische Landwirtschaft.
Mitt. Versuchssta. Angew. Entomol. Univ. Tartu — Mitteilungen der Versuchsstation für Angewandte Entomologie der Universität Tartu.
Mleev Hort. Exp. Sta. Bull. — Bulletin of the Mleev Horticulture Experiment Station.
Monogr. Pflanzenschutz — Monographien zum Pflanzenschutz.
Mont. Agr. Exp. Sta. Bull. — Montana Agricultural Experiment Station Bulletin.
N. Dak. Agr. Exp. Sta. Bi-Mon. Bull. — North Dakota Agricultural Experiment Station Bi-Monthly Bulletin.
N. Dak. Outdoors — North Dakota Outdoors.
N. & S. Dak. Hort. — North and South Dakota Horticulture.
Nachr. Schädlingsbekämpf. — Nachrichten über Schädlingsbekämpfung.
Nachrichtenbl. Deut. Pflanzenschutzdienst — Nachrichtenblatt für den Deutschen Pflanzenschutzdienst.
Natur Volk — Natur und Volk.
Nebr. Agr. Exp. Sta. Ext. Circ. — Nebraska Agricultural Experiment Station Extension Circular.
Nebr. Agr. Ext. Serv. Ext. Circ. (Processed) — Nebraska Agricultural Extension Service Extension Circular (Processed).
Nebr. Exp. Sta. Quart. — Nebraska Experiment Station Quarterly.
Neuh. Geb. Pflanzenschutzes — Neuheiten auf dem Gebiet des Pflanzenschutzes.
Notts. Educ. Comm., Nottingham — (Exact source unknown).
Notulae Entomol. — Notulae Entomologicae.
Ochr. Rostl. — Ochrana Rostlin.
Ohio Biol. Surv. Bull. — Ohio Biological Survey Bulletin.
Ohio J. Sci. — Ohio Journal of Science.
Oreg. Agr. Exp. Sta. Bull. — Oregon Agricultural Experiment Station Bulletin.
Pan-Pac. Entomol. — Pan-Pacific Entomologist.
Petrograd Kitchen Gard. — Petrograd Kitchen Gardening.
Plant Dis. Rep. — Plant Disease Reporter.
Plant Pathol. — Plant Pathology.
Plant Prot. (Belgrade) (Zašt. Bilja) — Plant Protection (Belgrade) (Zaštita Bilja).
Plantenziektenk. Dienst (Wageningen) — Plantenziektenkundigen Dienst (Wageningen).
Pol. Pismo Entomol. Ser. B Entomol. Stosow. — Polski Pismo Entomologiczne Seria B Entomologia Stosowana.
Prelim. Rep. Agr. Res. Sta. Rehovoth — Preliminary Report of the Agricultural Research Station, Rehovoth.
Proc. Conf. Pests Clover Cent. Russ. — Proceedings of the Conference on Pests of Clover in Central Russia.
Proc. Entomol. Soc. Manitoba — Proceedings of the Entomological Society of Manitoba.
Proc. Entomol. Soc. Ont. — Proceedings of the Entomological Society of Ontario.
Proc. Entomol. Soc. Wash. — Proceedings of the Entomological Society of Washington.
Proc. Forage Insect Res. Conf. — Proceedings of the Forage Insect Research Conference.
Proc. 12th Int. Congr. Entomol. (London) — Proceedings of the 12th International Congress of Entomology, London.
Proc. Lenin Acad. Agr. Sci. USSR — Proceedings of the Lenin Academy of Agricultural Sciences of the U.S.S.R.
Proc. N. Cent. Br. Amer. Assoc. Econ. Entomol. — Proceedings of the North Central Branch of the American Association of Economic Entomologists.
Proc. N. Cent. Br. Entomol. Soc. Amer. — Proceedings of the North Central Branch of the Entomological Society of America.
Proc. N. Dak. Acad. Sci. — Proceedings of the North Dakota Academy of Science.
Proc. Oreg. Seed Growers Leag. — Proceedings of the Oregon Seed Growers League.
Proc. Poltava Agr. Exp. Sta. — Proceedings of the Poltava Agricultural Experiment Station.
Proc. Zool. Soc. London — Proceedings of the Zoological Society of London.
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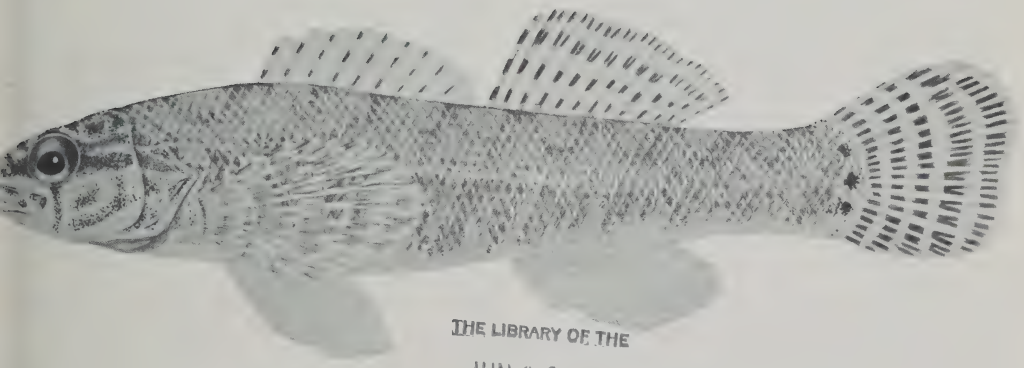
HE LIFE HISTORY OF THE SPOTTAIL DARTER,
'THEOSTOMA SQUAMICEPS,
I BIG CREEK, ILLINOIS, AND FERGUSON CREEK, KENTUCKY

ıwrence M. Page



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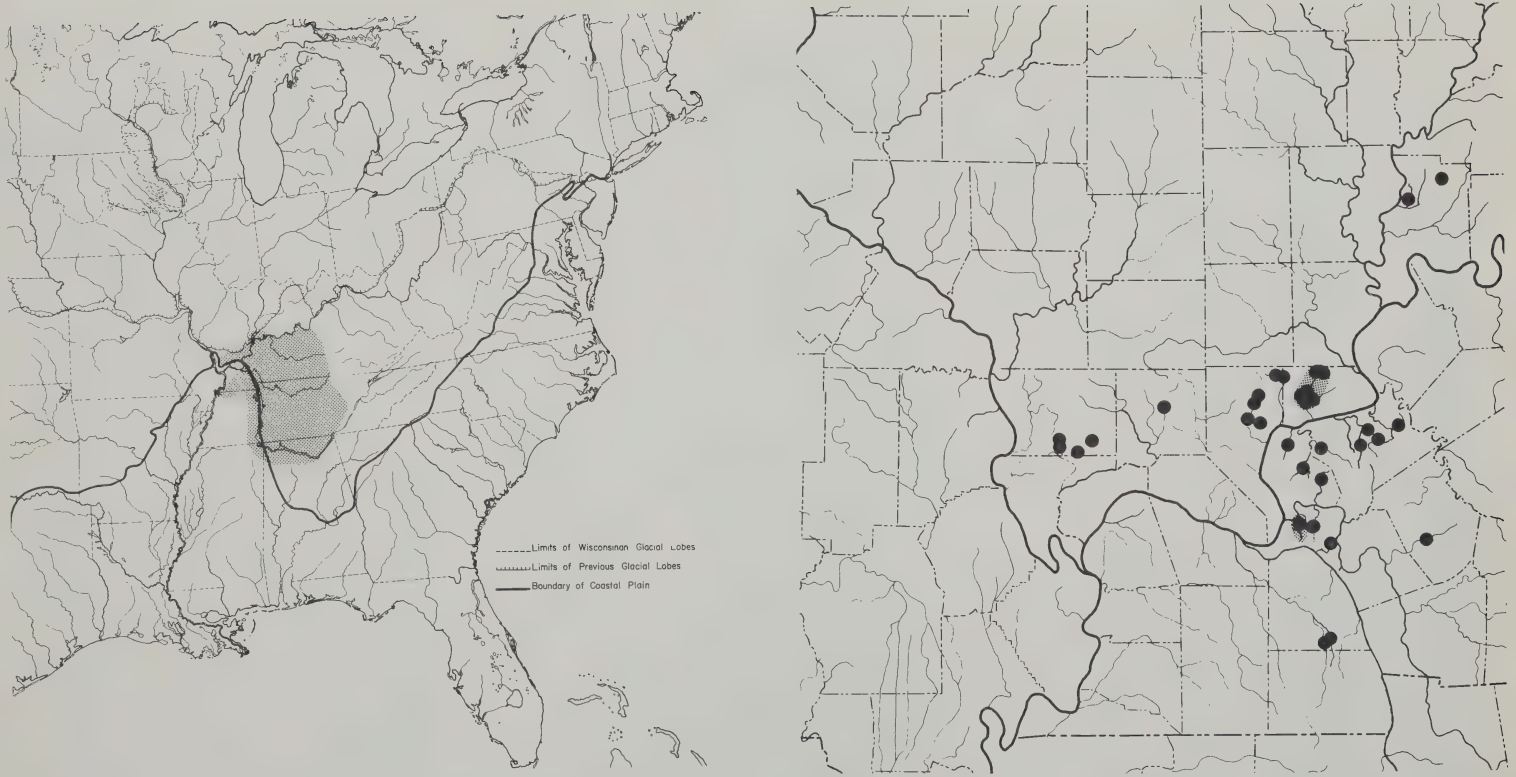

Fig. 1.—The total range (left) of *Etheostoma squamiceps* and the distribution of the species in Illinois and adjacent Kentucky and Indiana (right). The two study areas are shaded.

HE LIFE HISTORY OF THE SPOTTAIL DARTER, *ETHEOSTOMA SQUAMICEPS,* N BIG CREEK, ILLINOIS, AND FERGUSON CREEK, KENTUCKY

Lawrence M. Page

With the description of *Etheostoma barbouri* uehne and Small (1971) the number of described pecies of the subgenus *Catonotus* was raised to six. ther species are known but undescribed. All *atonotus* species except the wide-ranging *E. flabel-re* have relatively small ranges, and published eco-gical information on *Catonotus* species is limited brief notes in state ichthyofaunal reports and pecies descriptions and to studies on the reproduc-on and diet of *E. flabellare* (Lake 1936; Daiber 56; Winn 1958*a* and 1958*b*; Karr 1964).

The paucity of ecological information on *Catonotus* id the occurrence of four species of the subgenus a small area encompassing southeastern Illinois id adjacent Kentucky prompted life-history studies *E. squamiceps, E. kennicotti,* and *E. obeyense.* his report on *E. squamiceps* will be followed by milar accounts on *E. kennicotti* and *E. obeyense.*

Etheostoma squamiceps was described by Jordan 1877:11) from specimens collected at Russellville, ogan County, Kentucky. The range of the species Fig. 1) includes southern Illinois, southwestern Indi-na, western Kentucky, west-central Tennessee, and e Tennessee River drainage of Alabama (Smith-aniz 1968:106) and Mississippi (Cook 1959:207). lorphological descriptions of *E. squamiceps* are ven by Jordan (1877:11–12), Jordan & Evermann 896:1096), Forbes & Richardson (1908:312–313), owler (1922:26), Cook (1959:207), Moore (1968: 0), and Collette & Knapp (1966:39).

I am indebted to Brooks M. Burr, Ernest L. List, eorge W. Lewis, William Raino, Douglas W. chemske, Philip W. Smith, Richard L. Smith, Lewis Stannard, Jr., John A. Tranquilli, and John D. nzicker for aid in collecting specimens; to Dr. mith, Mr. Burr, and Mr. Schemske for counsel on umerous matters; to Mr. Schemske for identifying ost of the stomach contents; to Drs. David A. tnier and Vincent H. Resh for information on the istribution of *E. squamiceps;* and to Dr. Francis Kruidenier for identification of the acanthocephalan arasite.

The cover illustration was done by Mrs. Alice Ann Prickett, University of Illinois School of Life Sciences Artist. Assistance in preparing the other illustrations was provided by Illinois Natural History Survey Illustrator Lloyd LeMere and Survey Photographer Wilmer D. Zehr. The manuscript was edited for publication by Robert M. Zewadski, Associate Technical Editor of the Survey, and Dr. Howard E. Winn, University of Rhode Island, served as guest reviewer.

THE STUDY AREAS

Big Creek in Hardin County, Illinois, supports large populations of both *E. squamiceps* and *E. kennicotti,* and for this reason was selected as one of two streams to be used as study areas. Big Creek is a spring-fed, direct tributary of the Ohio River and lies in limestone formations of the Shawnee Hills. The upstream substrate is predominantly a mixture of slab rocks and gravel, the middle stream bed is mostly coarse gravel, and the downstream substrate is mostly sand. The stream system is forested throughout, and the water is usually quite clear.

General characteristics and fish populations of Big Creek were discussed by Lewis (1957), who found the most abundant fishes to be *Campostoma anomalum, Pimephales notatus, Notropis chrysocephalus,* and *Etheostoma caeruleum.* Other darters present in his collections were *Etheostoma kennicotti, E. squamiceps, E. nigrum,* and *Percina caprodes;* old records (Forbes & Richardson 1908) exist for *E. chlorosomum* and *E. asprigene.*

The second study area, Ferguson Creek in Livingston County, Kentucky, is a short, direct tributary of the lower Cumberland River and supports large populations of *E. squamiceps* and *E. obeyense.* The stream extends only about 3 miles, under normal conditions consists almost entirely of shallow slab-rock pools and slab riffles, and has a few deeper sand-bottomed pools. The most abundant fishes are *Pimephales notatus, Notropis umbratilis, Etheostoma obeyense, E. squamiceps,* and *Erimyzon oblongus.* Other species of darters in Ferguson Creek are *Etheostoma gracile, E. chlorosomum, E. asprigene, Percina maculata,* and *P. caprodes,* all of which are uncommon. Most observations and collections in

This paper is published by authority of the State of Illinois, S Ch. 127, Par. 58.12, and is a contribution from the Section of uunistic Surveys and Insect Identification of the Illinois Natural istory Survey, where Dr. Page is an Assistant Taxonomist.

COVER ILLUSTRATION: *Etheostoma squamiceps* collected in Gibbons Creek in Pope County, Illinois. From a drawing Mrs. Alice Ann Prickett.

Ferguson Creek were made near the Route 70 bridge 2 miles east of Smithland, a locality approximately 30 miles (48 km) from the Big Creek study area (Fig. 1).

Both study streams have three predominant habitats: riffles, slab pools, and non-slab pools. Riffles in Big Creek are mostly of coarse gravel, non-slab pools are only moderately deep (seldom over 1 m) and usually have a sand and gravel bottom, and slab pools are shallow with a substrate of gravel laden with slab rocks ranging from 100 to 400 mm across. In Ferguson Creek, slab pools have essentially the same physical characteristics as those of Big Creek, non-slab pools are generally deeper and almost exclusively sandbottomed, and riffles are of larger stones, mainly small slab rocks up to 150 mm across.

METHODS

Observations and minnow-seine collections were made at approximately monthly intervals except during spawning periods, when more frequent observations were made. Studies were begun in Big Creek on 6 October 1970 and in Ferguson Creek on 22 April 1971 and were terminated in both streams on 19 June 1973. Specimens collected for laboratory examination were preserved and stored in 10-percent formalin. From Big Creek 601 *E. squamiceps* and from Ferguson Creek 430 *E. squamiceps* were pre served and examined.

Beginning in August 1971, collections were mad by habitat in the two streams, and numbers specimens were recorded by month as having bee taken from riffles, slab pools, or non-slab pools. Wha was considered to be approximately the same samplin effort was expended on each of the three habitat Potential predators captured during seining operatio were preserved in formalin for later examination stomach contents. Field notes on ambient conditio and darter behavior were routinely taken.

By repeatedly seining a measured area until more darters were collected, quantitative sampl were taken in each of the three habitats in Ju 1972, October 1972, January 1973, and April 197

In the laboratory, all darters were sexed, measure and aged. Large specimens were sexed by examinir the genital papillae; small ones were sexed by exami ing the gonads. In addition to the standard lengt (SL) of all specimens, the lengths of the ana pectoral, pelvic, and soft-dorsal fins and the depths the caudal peduncles of 40 males and 40 femal of more than 30 mm SL from Ferguson Cre were measured as potential expressions of sexu dimorphism. Unless stated otherwise, measuremen in the text are standard lengths.

Aging to year class was done by counting t annuli on scales removed from the dorsum near t

TABLE 1. — Habitat distribution by percentages of *Etheostoma squamiceps* collected in Big and Ferguson Creeks b tween 25 August 1971 and 19 June 1973.

Month	Big Creek Sample				Ferguson Creek Sample			
	Number Collected	Percentage of *E. squamiceps* in			Number Collected	Percentage of *E. squamiceps* in		
		Slab Pools	Gravel Riffles	Non-slab Pools		Slab Pools	Slab Riffles	Non-sl Pool
				Adults				
January	3	100	0	0	15	7	93	0
February	9	100	0	0	9	33	67	0
March	4	100	0	0	5	0	100	0
April	4	100	0	0	3	100	0	0
May	37	57	0	43	16	19	81	0
June	8	100	0	0	8	0	100	0
July	6	100	0	0	3	0	100	0
August	22	100	0	0	8	0	100	0
September	30	100	0	0	13	30	70	0
October	21	86	9	5	1	0	100	0
November	11	100	0	0	9	11	89	0
December	5	80	20	0	4	0	75	25
				Young				
January	8	100	0	0	27	26	41	33
February	14	93	0	7	28	57	43	0
March	19	100	0	0	4	0	100	0
April	11	100	0	0	19	63	37	0
June	0	...	..	..	1	0	0	100
July	10	30	70	0	64	11	73	16
August	21	100	0	0	15	0	100	0
September	25	56	44	0	43	2	96	2
October	19	32	68	0	30	0	100	0
November	47	94	4	2	38	21	76	3
December	13	92	8	0	9	0	100	0

ction of the spinous and soft-dorsal fins. Aging month was done by using April, the month of the atest breeding activity in the study areas, as nth zero. Thus, a darter collected in September l having two scale annuli was estimated to have ed 2 years and 5 months. For certain comparisons darters were divided into young (through 12 months) and adult (over 12 months) age groups.

A representative sample of each collection was dissected to identify stomach contents and endoparasites and to note the conditions of the gonads. Weights of the ovaries of 87 females were obtained and recorded as a proportion of the adjusted body weight (the specimen minus the ovaries, stomach, intestine, and liver) of the female; the weight after the removal of the digestive system was used to eliminate variations resulting from the weight of recently ingested food. Mature ova from 18 preserved breeding females were counted.

In addition to specimens collected from the study areas during the study period, all *E. squamiceps* in the Illinois Natural History Survey collection were examined to ascertain probable spawning periods in other localities and other years. Indicators used were that males were in extreme breeding coloration and that females were heavy with mature ova.

The relative survival of each year class of the two populations was calculated by expressing the number of individuals in that year class as a proportion of the number of individuals in a younger year class.

The breeding behavior and territoriality of darters in laboratory aquaria were observed. Stream observations had indicated that territories centered naturally about large slab stones, and one or more slab stones (elevated slightly on small stones) were placed in each aquarium.

HABITAT

Adults of the Big Creek *E. squamiceps* population showed a distinct difference in their preference in habitat (as defined) from the preference of the Ferguson Creek adult population (Table 1). In Big Creek

Fig. 2.—(Upper Photo) Slab pool in the headwaters of Big Creek, Hardin County, Illinois. (Lower Photo) Slab riffles in Ferguson Creek, Livingston County, Kentucky.

they strongly preferred slab pools (Fig. 2) during all seasons and were seldom taken in riffles or in non-slab pools. In contrast, in Ferguson Creek adults were almost exclusively taken in slab riffles (Fig. 2) during the nonspawning seasons. During the height of the spawning season (April), adults of both populations were most common in the slab pools.

Comparative collections made at localities other than the study streams revealed that *E. squamiceps* adults are most commonly found in slab riffles, i.e., among and under small slab rocks (100–200 mm) characteristically forming the substrate of riffles in upper elevation streams. The seemingly dichotomous habitat preference found in the two study areas results from the strong association of the species with slab rocks. In Ferguson Creek both the riffles and the shallow pools have substrates composed of slab rocks, and *E. squamiceps* prefers the riffles. However, in Big Creek the riffles are of coarse gravel, or if of slab are very shallow, and *E. squamiceps* is forced to occupy the slab pools.

The occupation of slab pools in Big Creek indicates that slab rocks are more important to the species than other physical factors such as temperature and current. The slab pools of Big Creek are shallow and often become hot and stagnant in late summer, contrasting strongly with the cool, swift-flowing riffles of Ferguson Creek. The importance of slab rocks is further demonstrated by the absence of the species in Coastal Plain streams in extreme southern Illinois and elsewhere (Fig. 1), which typically lack a slab substrate.

Young *E. squamiceps* were somewhat more scattered throughout the stream systems than were the adults but still showed a rather strong preference for slab riffles in Ferguson Creek and for slab pools in Big Creek (Table 1). In Big Creek the young moved downstream from the spawning areas and were found generally distributed in slab pools and riffles throughout the stream system. The occupation of gravel riffles in Big Creek by a greater proportion of young than adults may reflect the capacity of young darters, in contrast to the larger adults, to hide among the coarse gravel. Winn (1958*b*:161) observed a similar lack of restriction of young *E. flabellare* to the large-rock riffles occupied by adults.

REPRODUCTION

Reproductive Cycle of the Male

The testes of the male *E. squamiceps* enlarged, as did the genital papilla (Fig. 3), as the spawning season approached. In breeding males testes were large, white, and spongy; following the spawning season the testes diminished in size and returned to the translucency characteristic of nonbreeding males. Breeding tubercles did not develop on *E. squamiceps* and are not thought to develop on any species of *Catonotus* (Collette 1965:603).

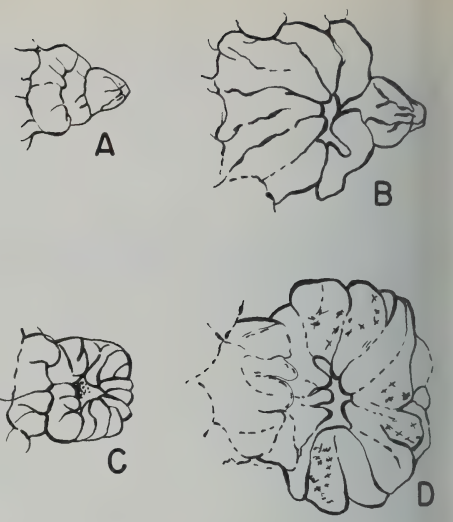

Fig. 3.—Genital papillae of *Etheostoma squamiceps*. A nonbreeding male; *B*, breeding male; *C*, nonbreeding f male; and *D*, breeding female. The nonbreeding specimer were 1+-year-old darters collected on 21 July; the breedir specimens were 2+-year-olds collected on 24 March. A papillae are shown 12 times actual size.

In early spring large males became very dar and could be sexed on sight. The darkening of th male prior to spawning is a phenomenon observe in several other species of darters, including th closely related *E. flabellare* (Lake 1936:818; Win 1958*b*:172), *E. nigrum* (Winn 1958*b*:172), and se eral species of *Percina* (Winn 1958*b*:172; Page Smith 1970:6 and 1971:6).

The most extreme breeding pigmentation was ob served on males in aquaria spawning (Fig. 7) an nestguarding. In contrast to the female and th nonbreeding male, the breeding male was witho the typical mottled pattern. The entire head to th posterior margin of the opercle was black and swolle From the head to below the junction of the dors fins the body was nearly white. The posterior ha of the body was boldly marked with 7 or 8 vertic bars. The three caudal spots were coalesced into vertical bar. The flesh over the anal spines w thickened. All fins except the pectorals blackene but the caudal and soft-dorsal fins retained the characteristic clear banding. The membranes of th spinous-dorsal fin were black except for a proxim zone without pigment. The spines of the spinou dorsal fin were tipped with small, white knobs, ea knob being preceded by a small but prominent bla spot. The rays of the soft-dorsal fin were tipp with small knobs, white in some individuals a black in others.

Males of *E. squamiceps* selected cavities und slab rocks as future nesting sites (Fig. 4) a fe

Fig. 4.—A typical nesting site of *Etheostoma squamiceps* photographed in Big Creek on 22 April 1971. The male was guarding his nest beneath a slab rock.

ys or weeks before spawning and vigorously de-nded them against intruders. Such a cavity was ways cleaned of silt and debris; in contrast, lifting stone which did not harbor a *Catonotus* male be-ath it always released a flurry of small debris. ie requirement noted for *E. flabellare* (Winn 58*a*:208), that to be used as a nest site a stone ist be between 1.5 and 2.5 cm above the substrate, is not found for *E. squamiceps*.

Aquarium-held males were observed to shake their ls repeatedly and vigorously under stones selected nest sites, forcing out silt and small gravel and larging the cavity. One male was observed to shake e posterior half of his body with the soft-dorsal against the bottom of the nest stone, apparently eaning the area to be used for egg deposition.

In both Ferguson and Big creeks the largest con-ntrations of nests were found in the shallow (to 0 mm) slab pools in the uppermost portions of e stream systems, where the stream beds were pically 1–3 m wide and the current slight but servable. A few nests were found in slab riffles Ferguson Creek and in spring runs in Big Creek. eep water (over 400 mm) was usually avoided; wever, during the prolonged 1973 spring floods *squamiceps* was found spawning in water as deep 600 mm.

Only large males developed the breeding pattern, derwent gross enlargement of the testes, and were ınd guarding nests. These large males probably did ost or all of the spawning. Young males that had not ached a standard length of 40 mm by the end the spawning season did not have enlarged testes d presumably were not sexually mature. All males 40 mm or more appeared to be sexually mature; however, there was no evidence that 1-year-old males actually spawned.

Reproductive Cycle of the Female

Generally, the largest *E. squamiceps* females of all age-classes spawned the earliest in the season although a few 1-year-old females as small as 40 mm spawned as early as 24 March. A few females as small as 35 mm spawned in late April and early May.

TABLE 2. — Relationship between size, age, and ovary weight of *Etheostoma squamiceps* females and the number of mature ova produced. An age of 1 year = 11–13 months, 2 years = 23–25 months, 3 years = 35–36 months.

Standard Length in mm	Adjusted Body Weight in Grams[a]	Age in Years	Ovary Weight in Grams	Number of Mature (Orange or Translucent) Ova
32	0.57	1	0.07	54
35	0.59	1	0.06	44
37	0.74	1	0.21	80
40	0.93	1	0.17	40
41	0.85	2	0.15	56
42	1.11	2	0.25	70
43	1.05	1	0.23	50
44	1.18	2	0.20	64
48	1.27	2	0.12	28
48	1.79	2	0.37	140
48	1.64	2	0.32	110
49	1.71	2	0.33	132
51	2.27	2	0.60	91
51	2.16	2	0.33	116
55	2.56	2	0.21	80
55	2.77	3	0.72	234
57	3.32	3	0.78	227
58	3.22	3	0.79	357

[a] Adjusted body weight is the specimen's weight after the removal of the ovaries, stomach, intestine, and liver.

In contrast to males, females did not undergo a color and pattern change with the approach of the spawning season. The most evident morphological changes associated with spring were a marked distention of the belly, accompanying the presence of maturing ova, and an enlargement of the genital papilla (Fig. 3). Enlargement of the papilla in most females was evident by February; gross distention of the belly preceded spawning by only a few days or weeks.

Small white ova were present in most females by October, but in very small females ova did not appear until December. Larger yellow ova began appearing in December and were present in most females by February. Large, maturing orange ova appeared in March and April. Just prior to spawning the mature ova lost their orange opacity and became translucent. The oldest and largest females produced the largest numbers of mature ova; the youngest and smallest generally produced the fewest. The number of mature ova counted in 18 females ranged from 28 to 357 (Table 2). For these females the relationship between the number of mature ova (F) and the adjusted body weight (W) was $F = -27.12 + 83.88W$, with $r = 0.845$, and between the number of mature ova and the standard length (L) was $\log F = -2.589 + 2.729 \log L$, with $r = 0.691$.

Estimates of the number of eggs laid in aquaria by individual females were 50 (by a 57-mm, 3-year-old), 50 (by a 62-mm, 3-year-old), 20 (by a 41-mm, 1-year-old), and 120 (by a 54-mm, 2-year-old). Mature ova averaged 1.6 mm in diameter, were translucent, and contained a single oil droplet.

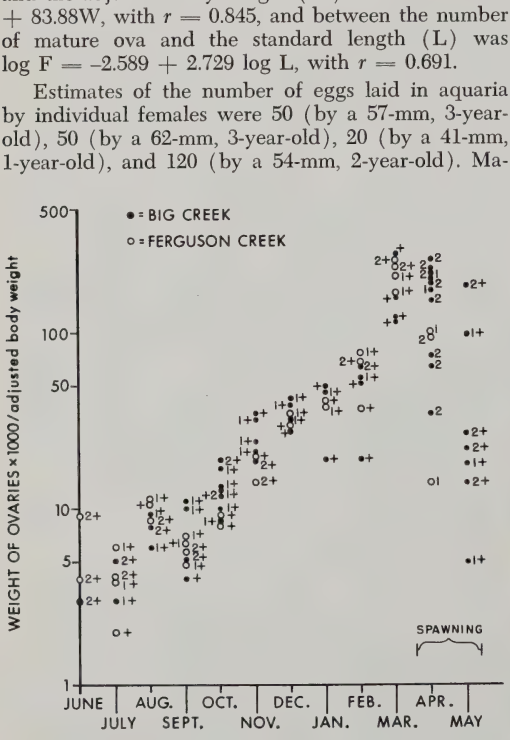

Fig. 5.—Monthly variations in ovarian weight relative to adjusted body weight of *Etheostoma squamiceps*. The vertical axis is a logarithmic scale. The number beside each dot is the age of the female. The lower five dots for May represent postspawning females.

Spawning and the subsequent absorption of remaining immature ova resulted in a rapid decrease in the size of the ovaries. Ovaries of postspawning females collected in April and May contained only small, white ova and were very small in comparison to ovaries of prespawning females collected in March and April (Fig. 5). Ovaries increased markedly in size between the recovery period and the spawning period in the following spring (Fig. 5). The proportionally largest ovaries (equalling 26.4 percent and 28.7 percent, respectively, of the adjusted body weights of the females) were found in a 2-year-old, 51-mm female collected in Big Creek on 9 April 1971 and in a 1-year-old, 37-mm female collected in Big Creek on 31 March 1973. Ovary-weight-to-adjusted-weight ratios ranged from 0.091 to 0.287 and averaged 0.189 in the 18 females represented in Table 2.

Spawning

E. squamiceps spawned at the study areas from late March through May on the undersides of the slab rocks (Fig. 6) selected as nesting sites by the males. Temperatures at which spottail darters were found spawning ranged from 14° to 19° C. These temperatures usually prevailed from late March to late May, warming from temperatures ranging from 3° to 10° C in January, February, and early March.

Nests of *E. squamiceps* were found in Trousdale County, Tennessee, on 21 April 1973 and in Todd County, Kentucky, on 22 April 1973. Late March was the most probable time of spawning for *E. squamiceps* collected at other localities (Table 3).

Eight spawnings occurred in the laboratory, five of which were observed. Four of the spawnings occurred in the morning hours, one in the afternoon, and three during the night or early morning. Aquarium temperatures ranged from 19° to 25° C.

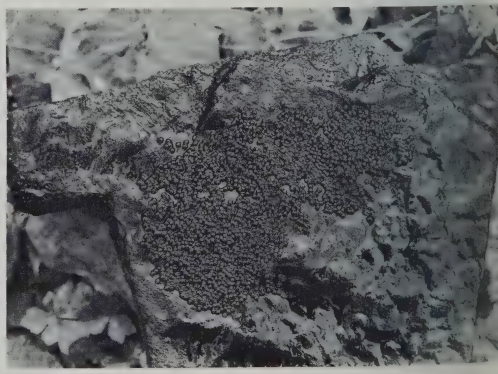

Fig. 6.—Eggs of *Etheostoma squamiceps* on the underside of a stone removed from a slab pool in the headwaters of Big Creek on 22 April 1971.

TABLE 3. — Collections of breeding *Etheostoma squamiceps*.

Locality	Collection Date	Remarks
erguson Creek, Livingston Co., Ky.	24 March 1972	Spawning when collected.
erguson Creek, Livingston Co., Ky.	23 March–20 May 1973	Spawning when collected.
ig Creek, Hardin Co., Ill.	15 April–3 May 1971	Spawning when collected.
ig Creek, Hardin Co., Ill.	31 March–20 May 1973	Spawning when collected.
ickory Creek, Livingston Co., Ky.	27 March 1964	Female in extreme breeding condition.
uck River, Coffee Co., Tenn.	28 March 1965	Male in extreme breeding coloration.
ush Creek, Posey Co., Ind.	29 March 1963	Males and females in extreme breeding condition.

Preceding spawning, males periodically left the est stone to court females. When attempting to lure female back to the stone, a male would swim near female, display his bold pattern and spread fins, nd wag his tail at or against the female.

After joining a male under his nest stone, a female sually remained passive while the male courted her. he male was extremely active at this time, con-antly darting about, nudging the female with his nout, and occasionally bobbing his spinous dorsal n up and down, the contrasting dark and clear reas of which created a blinking effect.

Eventually the female began moving about, arch-ng her head upward, and holding her snout near ne underside of the stone, apparently selecting a te for egg deposition.

Both male and female assumed an inverted posi-on when laying and fertilizing eggs. After nosing bout the rock for a time, the female rolled to one de and simultaneously rose to press her venter gainst the underside of the nest stone. Usually almost mmediately after the female had inverted, the male olled to one side and positioned himself tightly along-de and slightly overlapping the female, with a elvic fin across her nape, in an inverted head-to-head osition (Fig. 7). Pressed against the stone, the emale began quivering slightly, barely moving for-ard as she did so, and laying a series of two to ve eggs on the stone. As she laid the eggs, the ale trembled and released sperm. Then both fish mmediately returned to a right-side-up position be-eath the stone for a short time before courting y the male began the sequence again.

Fifteen seconds to several minutes elapsed be-veen inversions. Each inversion lasted less than seconds. The eggs were concentrated in a con-ricted area but never were laid on top of other ggs. Eggs were deposited as high as 35 mm above ne substrate.

The presence of a second female with a spawning air was tolerated, and in fact, both females were ourted by the male. No instances of more than one f the females spawning at a time were observed, owever.

At least three females spawned with one male n an aquarium, two with another. In one instance the pawnings with different females occurred within 2 hours of one another; in another instance the spawnings were 5 days apart. Eggs laid by a second or third female were added to those already in the nest, enlarging the concentrated egg mass.

Counts and estimates of the numbers of eggs in 20 nests of *E. squamiceps* found in Big and Ferguson creeks were 8, 90, 125, 125, 160, 200, 200, 200, 200, 250, 275, 300, 450, 475, 475, 500, 850, 1100, 1500, and 1500, the mean being 449. Several nests contained many more eggs than the largest number of mature ova (357) found in preserved females and, as in aquarium nests, contained eggs from more than one female. Eggs in nests averaged 1.8 mm in diameter.

Males vigorously guarded the eggs. Whenever a nest stone in a stream was lifted for observation, a male was found underneath and usually swam away only when provoked. When a male did dart away, he usually returned soon after the rock was replaced. In all nests which were re-examined on a later date, the male had returned and was again guarding the nest.

Aquarium-held males were constantly active while guarding eggs, darting back and forth and continuously brushing the eggs with their dorsal fins. The knobs on the tips of the dorsal spines of *E. squamiceps* males may be an adaptation to reduce the sharpness of the spines, thereby reducing the probability of rupturing eggs, during the nest-guarding time. Periodic nipping at the eggs presumably removed invading organisms. The breeding pattern of the male was retained during the egg-guarding period.

Nests were guarded against potential egg predators, including crayfishes. Large crayfishes introduced into aquaria were driven from the nest stone by the male *E. squamiceps* as he repeatedly charged the crayfishes and bit them or hit them on the abdomen. A 63-mm male *E. squamiceps* succeeded in driving from his nest a 75-mm total length *Orconectes kentuckiensis* but not a 90-mm *Cambarus laevis*, both common crayfishes in Big Creek.

Nests were never tended by females. Lake (1936: 823) believed that only *E. flabellare* males provide parental care to their eggs.

Some areas used as breeding grounds contained large numbers of nests. Separate nest stones of *E. squamiceps* were found as close as 200 mm from one another. Two large stones with two *Catonotus* nests

Fig. 7.—*Etheostoma squamiceps* spawning in aquaria. A nest of eggs is on the underside of the stone above each pair of darters.

nder each were located; one had two nests of *E. quamiceps* (approximately 200 mm apart); the ther had one nest of *E. squamiceps* and one of *E. ennicotti*. In both instances of double occupancy f a nest stone, the two nests were completely sep-rated from one another by substrate material when ie rock was in place in the stream. Similar sharing f one nest stone was described by Lake (1936:823))r *E. flabellare*.

The spawning behavior of E. *squamiceps* is similar) that of *E. flabellare*, described by Lake (1936) nd Winn (1958*a* and 1958*b*). Differences in the)awning behavior of *E. flabellare* from that of *E. quamiceps* are the head-to-tail egg-laying position, ie fact that females may remain inverted for as)ng as 2 hours, the habit of the female of usually ying only one egg at a time, and the intolerance y the male of the presence of a right-side-up female nder the nest stone.

exual Dimorphism

Winn (1958*b*:172) listed among the sexually morphic characters of *E. flabellare* the larger anal, ectoral, and pelvic fins of the male. In addition behavioral (territorial) and morphological (colora-)n and size) differences between the sexes of *E. uamiceps*, the anal, soft-dorsal, pelvic ($P<0.01$), id pectoral fins ($P<0.10$) were significantly longer males. The depth of the caudal peduncle was also eater in males ($P<0.01$).

DEVELOPMENT AND GROWTH

Eggs incubated in aquaria at temperatures vary-g from 18° to 22°C (64°–72°F) hatched in 270–275)urs (11.3–11.5 days), and eggs incubated at 22°–°C (72°–79°F) hatched in 125–130 hours (5.2–5.4 ys).

Three nests of *E. squamiceps* eggs were found to hatching in Big Creek on 3 May 1971, including e nest first discovered and marked on 17 April. iis nest had been observed periodically between April and 3 May, during which time water tem-ratures varied from 14° to 18°C (57°–64°F). No gs were added during this time; thus, a minimum 16 days of incubation is required at this tempera-re range. Lake (1936:826) found eggs of *E. flabel-e* to have much longer incubation periods: 14–16 ys at an average temperature of 74°F, 21 days at °–71°F, and 30–35 days at 63°–68°F.

E. squamiceps hatchlings (Fig. 8) were 6.5 mm in total length and mostly translucent, but they had red blood, black melanophores over most of the body, and metallic gold eyes. Melanophores were especially prominent on top of the head and on the lower one-third of the yolk sac. Pectoral fins and the lower jaw were well developed, as they are in *E. flabellare* hatchlings (Lake 1936:826–827), making these two species more precocious at hatching than are *Etheostoma gracile* (Braasch & Smith 1967:9) and *Percina sciera* (Page & Smith 1970:9).

In aquaria, fry left the nest stone soon after hatching and sought refuge among the gravel substrate. Propulsion was accomplished by rapid movements of the caudal fin.

The smallest specimens examined from the study areas were two 12-mm females collected 20 July 1971 in Big Creek. Several specimens from 13 to 20 mm were collected in a number of habitats in both study areas between 23 June and 25 August of 1971 and 1972.

At 12 mm juveniles had essentially the morphology of adults but were without scales on the nape, breast, and belly, and were without a lateral-line canal. In

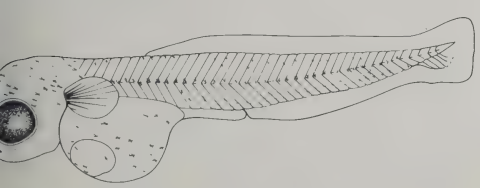

Fig. 8.—*Etheostoma squamiceps* hatchling.

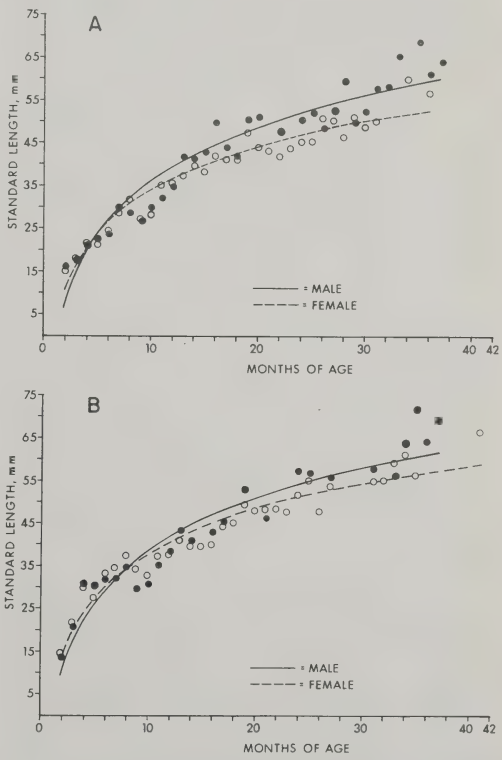

Fig. 9.—Size distribution by age of *Etheostoma squamiceps* collected in *A*, Big Creek, and *B*, Ferguson Creek. Black circles represent sample means for males; white circles represent sample means for females. From Big Creek 601 specimens were collected, and from Ferguson Creek 430.

TABLE 4. — Standard lengths of *Etheostoma squamiceps* at 1, 2, and 3 years (12, 24, and 36 months) of age. These specimens were collected in April 1971 and 1973.

Study Area and Sex	Age	Number	Standard Length		
			Mean	Range	Standard Deviation
Big Creek males	1	15	34.8	27.1–43.2	4.1
Big Creek females	1	22	36.2	28.0–43.1	4.1
Ferguson Creek males	1	3	37.7	27.4–46.7	9.7
Ferguson Creek females	1	21	37.2	31.9–44.6	4.0
Big Creek males	2	17	51.3	43.3–59.8	4.4
Big Creek females	2	33	45.5	37.9–55.3	4.4
Ferguson Creek males	2	2	57.5	51.4–63.5	8.6
Ferguson Creek females	2	4	54.7	48.0–55.6	4.9
Big Creek males	3	5	61.2	53.5–65.9	5.4
Big Creek females	3	3	57.4	56.2–58.7	1.3
Ferguson Creek males[a]	3	2	64.6	62.3–66.9	3.3

[a] No 3-year-old females were found in Ferguson Creek.

contrast to the mottled pattern of adults, they had a pattern consisting of large spots over all areas of the body except the belly. At 16 mm the lateral-line canal had begun to form. At 19 mm the mottled pattern characteristic of the adult was present; scales were present on the nape, breast, and belly; and the lateral line extended to the soft-dorsal fin.

Both populations studied grew at nearly the same decreasing rate (Fig. 9). The equation expressing the relationship between standard length (Y) and age in months (X) of Big Creek males is $Y = -7.00 + 42.83 \log X$, $r = 0.958$; of Big Creek females is $Y = -0.35 + 34.21 \log X$, $r = 0.962$; of Ferguson Creek males is $Y = -3.08 + 41.99 \log X$, $r = 0.921$; and of Ferguson Creek females is $Y = 3.19 + 34.92 \log X$, $r = 0.947$.

During the first year of growth sex had little influence on the growth rate. During subsequent years, however, males grew more rapidly than did females (Fig. 9), and by the third year males were significantly larger than females ($t = 3.78$, df = 53 for the Big Creek population; $t = 2.79$, df = 27 for the Ferguson Creek population). Males in younger year classes were not significantly larger than females. The largest specimen examined was a 72-mm male from Ferguson Creek. Table 4 presents the standard lengths of 1-, 2-, and 3-year-old *E. squamiceps* collected in April.

E. squamiceps reached one-half of the first year's mean growth in approximately 12 weeks; this period is much longer than that required for *E. gracile* (1 week, Braasch & Smith 1967:9) and *Percina phoxocephala* (2 weeks, Page & Smith 1971:9).

Although captive *E. squamiceps* individuals occasionally swam up and down the side of an aquarium seeking to escape, the species in general has almost totally benthic habits. Both field and aquarium observations indicated that the fry, juveniles, and adults mainly rest on the substrate or dart about in short, jerky movements. The only rapid swimming observed in the field were escape maneuvers, which usually involved distances of less than 2 m.

DEMOGRAPHY

Density

On four separate dates at approximately 3-month intervals, quantitative samples of *E. squamiceps* were taken in both Big and Ferguson creeks by repeatedly seining a measured area of stream until no more darters were collected. The number of specimens collected was transposed into the number per square meter (Table 5).

In Big Creek the highest density of adults was consistently found in the slab pools. In Ferguson Creek the highest densities of adults during the nonspawning season were in the slab riffles and in April were in slab pools, where they had moved to spawn.

Young darters in Big Creek were common in both slab pools and riffles in summer and autumn, but common only in the slab pools in winter and spring. Young in Ferguson Creek were consistently most common in the slab riffles although at 1 year of age many had moved to the slab pools where the spawning activity was greatest.

Including both young and adults, the greatest density of *E. squamiceps* in Ferguson Creek (9.6 per m^2) was in the slab riffles in July, and in Big Creek the greatest density (2.0 per m^2) was in the slab pools in April.

Composition

Of the 601 *E. squamiceps* collected in Big Creek, 55.7 percent were up to 1 year of age, 34.6 percent were over 1 and up to 2 years of age, 9.2 percent were over 2 and up to 3 years, and 0.5 percent were over 3 years. Of the 430 specimens collected in Ferguson

TABLE 5. — Number of *Etheostoma squamiceps* individuals per square meter collected at approximately 3-month intervals, by habitat. Young were up to 1 year of age, adults over 1 year.

Collection Date	Big Creek Sample				Collection Date	Ferguson Creek Sample			
	Number Collected	Number of *E. squamiceps* Per Square Meter in				Number Collected	Number of *E. squamiceps* Per Square Meter in		
		Slab Pools	Gravel Riffles	Non-Slab Pools			Slab Pools	Slab Riffles	Non-Slab Pools
				Adults					
July 1972	6	0.81	0.0	0.0	8 July 1972	3	0.0	0.58	0.0
October 1972	9	0.73	0.63	0.05	20 October 1972	1	0.0	0.27	0.0
January 1973	2	0.22	0.0	0.0	16 January 1973	5	0.04	0.63	0.0
April 1973	4	0.54	0.0	0.0	30 April 1973	3	0.25	0.0	0.0
	MEAN	0.58	0.16	0.01		MEAN	0.07	0.37	0
	SD	0.26	0.32	0.03		SD	0.12	0.29	
				Young					
July 1972	10	0.40	0.60	0.0	8 July 1972	64	0.25	9.03	1.08
October 1972	4	0.24	0.63	0.0	20 October 1972	30	0.0	8.07	0.0
January 1973	7	0.77	0.0	0.0	16 January 1973	21	0.27	1.11	0.39
April 1973	11	1.48	0.0	0.0	30 April 1973	19	0.99	1.26	0.0
	MEAN	0.72	0.31	0		MEAN	0.38	4.87	0.37
	SD	0.55	0.36			SD	0.43	4.27	0.51

reek, 72.1 percent were up to 1 year of age, 20.5 ercent were over 1 year and up to 2 years, 6.7 ercent were over 2 and up to 3 years, and 0.7 ercent were over 3 years. The very small number these darters over 3 years of age effectively demstrates that 3+ is the maximum age of *E. squamips* (Table 6).

A skewed sex ratio was found in each study opulation, both among the young [1.3 females to male in Big Creek ($x^2 = 5.52$; $P<0.025$), 1.7 to 1 Ferguson Creek ($x^2 = 20.64$; $P<0.005$)] and ong the total samples [1.3 to 1 in Big Creek ($x^2 = .02$; $P<0.005$), 1.9 to 1 in Ferguson Creek ($x^2 = .01$; $P<0.005$)]. The only year class in which males edominated was 3+, indicating a greater longevity r males.

The skewed sex ratios among young-of-the-year ottail darters suggest a genetic rather than a direct vironmental cause for the predominance of females. ie absence of spawning activities by all but the large males (a small proportion of the population) and the fact that several females may contribute to the nest of one male may have resulted in selection against a 50-50 sex ratio.

TABLE 6. — Distribution of sexes and year classes in nples of *Etheostoma squamiceps* collected between 6 Ober 1970 and 19 June 1973.

Sex	Number by Year Class				Total
	−1	1+	2+	3+	
		Big Creek			
Male	146	83	26	3	258
Female	189	125	29	0	343
Total	*335*	*208*	*55*	*3*	*601*
		Ferguson Creek			
Male	115	18	12	2	147
Female	195	70	17	1	283
Total	*310*	*88*	*29*	*3*	*430*

Survival

Relative survival values (Table 7) for each year of life were calculated for males, females, and total samples of *E. squamiceps*, using the data in Table 6. It was assumed that each age class was collected in proportion to its relative number in the population, that the population was neither increasing nor decreasing, and that the number of fry entering the population each year was constant.

Because approximately one-third of the sampling effort each month was expended in the slab pools, which constitute less than one-third of the habitat of Big Creek but in which adults tended to be concentrated (Tables 1 and 4), the number of adults in Table 6 probably exaggerates their actual proportion in the population. Survival was therefore computed on the 1+ year class as well as the −1 year class (Table 7).

The general shapes of survival curves for males, females, and total samples (Fig. 10) were similar to one another except for the Ferguson Creek male $1x^1$ curve. The increasing steepness of the slope with age reflects the lower rate of survival for each age class. The unusual shape of the Ferguson Creek male $1x^1$ curve is a result of the very low number of 1+ males and is probably due to sampling error.

The decrease in survival of *E. squamiceps* with each year of life demonstrates a tendency toward a life-span characteristic of the species (Deevey 1947: 286). Very few individuals of either sex live longer than 3 years. The oldest *E. squamiceps* examined

was (assuming an April hatching) a 3-year, 5-month-old female from Ferguson Creek.

TABLE 7. — Relative survival of year classes of *Etheostoma squamiceps* expressed as proportions of the —1 year class ($1x^1$) and the 1+ year class ($1x^2$).

Sample	Year Class	Number of Specimens	Survival $1x^1$	Survival $1x^2$
		Big Creek		
Males	—1	146	1.000	...
	1+	83	0.568	1.000
	2+	26	0.178	0.313
	3+	3	0.021	0.036
Females	—1	189	1.000	...
	1+	125	0.661	1.000
	2+	29	0.153	0.232
	3+	0	0.000	0.000
Total sample	—1	335	1.000	...
	1+	208	0.620	1.000
	2+	55	0.164	0.264
	3+	3	0.008	0.014
		Ferguson Creek		
Males	—1	115	1.000	...
	1+	18	0.156	1.000
	2+	12	0.104	0.666
	3+	2	0.017	0.111
Females	—1	195	1.000	...
	1+	70	0.359	1.000
	2+	17	0.087	0.242
	3+	1	0.005	0.014
Total sample	—1	310	1.000	...
	1+	88	0.284	1.000
	2+	29	0.093	0.329
	3+	3	0.010	0.034

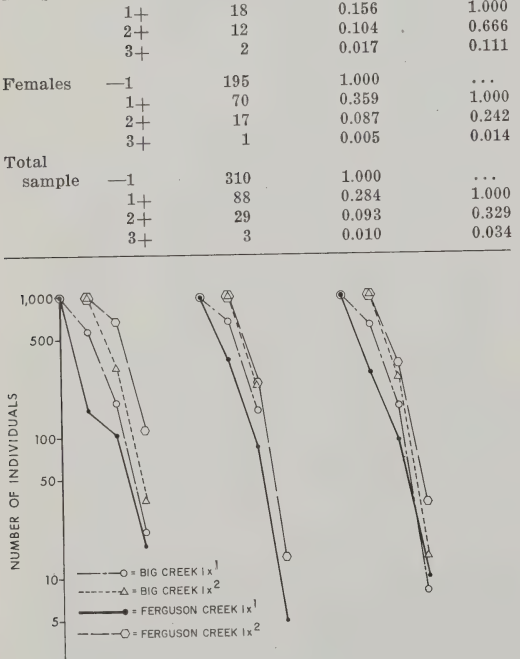

Fig. 10.—Survival curves for *Etheostoma squamiceps*. Points on the curves were obtained by multiplying the data in the survival columns of Table 6 by 1000. The vertical axis is a logarithmic scale.

Migration

After hatching in the upstream slab pools, young *E. squamiceps* dispersed throughout the Big Creek system, mostly moving downstream. As they approached 1 year of age, the darters returned to upstream concentrations of slab rocks, where they generally remained the rest of their lives (Table 1). For the majority of the Big Creek population the dispersal as young from the spawning grounds and the upstream return to slab pools by 1 year of age were the only major migratory movements.

An indication of the magnitude of the upstream spring migration of 1-year-old *E. squamiceps* was the large number of individuals collected at a bridge dam on a headwater tributary of Big Creek on 3 March 1973. Darters moving upstream were unable to get around the bridge and were concentrated in large numbers. One seine haul covering approximately 4 square meters yielded over 50 *E. squamiceps;* all were 1-year-old (11 months) fish.

For the majority of the Ferguson Creek population, migratory movements consisted of an annual exodus each spring from the slab riffles into the slab pools, where most of the spawning activity occurred and then a return to the riffles.

Territoriality

Aquarium and field observations indicated that *E. squamiceps* breeding males are strongly territorial; females and nonbreeding males are only weakly territorial.

When actively defending a territory, males were boldly patterned with vertical banding and a darkened head and fins; breeding and nest-guarding males had especially bold patterning. The threat posture of a male was a lateral display of his pattern and erected median fins. Persistent intruders were chased from the territory.

Occasionally when two or more breeding males were introduced into an aquarium, they briefly battled to determine the ownership of a nest stone. Such combat consisted of repeated threat display, nipping, and tail wagging against one another.

The selective advantage for an aquarium-held male in establishing and holding a nest territory was evident: all females after the first to spawn laid eggs only in an already existing nest, and therefore the first male to spawn was the only male to spawn.

In a large aquarium in which the males established territories centered about slab stones and several females were forced to share the remaining limited area, one female became highly belligerent toward the other females and seemed to be guarding a nonstationary territory. She was easily recognized having a darkened head and vertical bands similar to those of a territorial male.

DIET

Stomach contents of 173 *E. squamiceps* from Big Creek and of 67 from Ferguson Creek were

examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred											
	Big Creek											
	Jan. (13)	Feb. (12)	Mar. (9)	Apr. (11)	May (12)	June (7)	July (28)	Aug. (18)	Sept. (16)	Oct. (17)	Nov. (16)	Dec. (14)
Nematoda	..	8.3	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	25.0	..	..	..	..	..	..	..	..	..	7.1
Gastropoda	..	8.3	11.1	..	8.3	14.3	7.1	..	12.5	5.9	6.3	14.3
Arachnida												
Araneae	..	..	..	..	..	..	..	..	..	..	..	..
Acarina	..	..	..	..	..	14.3	3.6	11.1	..	..	..	..
Crustacea												
Cladocera	..	..	..	..	..	..	7.1	16.7	18.8	41.2	..	..
Ostracoda	..	..	..	..	..	42.9	25.0	22.2	6.3	11.8	..	..
Copepoda	15.4	50.0	..	9.1	8.3	28.6	10.7	5.6	25.0	35.3	56.3	28.6
Isopoda												
Asellidae	7.7	16.7	..	27.3	8.3	..	..	5.6	..	..	25.0	50.0
Amphipoda	7.7	75.0	..	90.9	..	14.3	7.1	5.6	..	35.3	..	14.3
Decapoda												
Astacidae	..	..	..	9.1	25.0	..	..	..	..	..	..	..
Insecta												
Plecoptera	46.2	8.3	..	9.1	..	..	..	..	..	..	..	28.6
Ephemeroptera	23.1	33.3	11.1	..	41.7	42.9	39.3	50.0	56.3	58.8	25.0	21.4
Odonata												
Zygoptera	..	8.3	..	..	..	..	..	..	..	..	..	..
Trichoptera	7.7	16.7	..	9.1	8.3	..	..	..	6.3	5.9	..	14.3
Coleoptera												
Dytiscidae	..	8.3	..	..	..	..	..	..	..	..	..	..
Hydrophilidae	..	8.3	..	..	8.3	..	..	..	..	..	..	..
Psephenidae	..	16.7	..	..	..	..	3.6	5.6	12.5	..	..	..
Elmidae	..	8.3	..	..	8.3	..	..	5.6	6.3	..	..	..
Diptera												
Tipulidae	..	..	..	..	..	..	..	..	..	..	..	..
Simulidae	..	..	..	..	..	..	..	..	..	..	..	..
Chironomidae	30.8	75.0	88.9	90.9	83.3	57.1	35.7	38.9	37.5	23.5	75.0	64.3
Ceratopogonidae	..	8.3	..	..	..	..	3.6	..	..	..	..	..
Others	7.7	16.7	..	..	..	..	10.7	..	6.3	5.9	..	..
Miscellaneous	..	8.3	..	27.3	..	..	..	..	..	..	..	7.1

Food Organism	Ferguson Creek											
	Jan. (3)	Feb. (7)	Mar. (3)	Apr. (6)	May (6)	June (5)	July (13)	Aug. (6)	Sept. (6)	Oct. (3)	Nov. (6)	Dec. (3)
Nematoda	..	..	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	..	..	..	..	..	..	..	..	..	..	..
Gastropoda	..	28.6	..	..	..	..	..	..	..	..	..	..
Arachnida												
Araneae	..	..	..	..	..	20.0	7.7	..	16.7	..	..	..
Acarina	..	..	..	..	..	..	7.7	..	..	..	..	..
Crustacea												
Cladocera	..	..	..	..	..	..	30.8	..	..	..	..	..
Ostracoda	..	..	..	..	..	20.0	7.7	..	..	..	..	..
Copepoda	..	..	..	..	..	..	46.2	..	..	..	..	..
Isopoda												
Asellidae	..	14.3	33.3	16.7	16.7	..	7.7	16.7	..	..	..	100.0
Amphipoda	..	..	33.3	..	33.3	..	7.7	16.7	16.7	..	66.7	33.3
Decapoda												
Astacidae	..	..	..	..	..	..	..	..	..	..	..	..
Insecta												
Plecoptera	..	14.3	..	..	..	..	..	..	..	..	..	..
Ephemeroptera	33.3	..	..	..	16.7	20.0	7.7	33.3	..	66.7	50.0	33.3
Odonata												
Zygoptera	..	..	..	..	..	..	..	..	..	..	..	..
Trichoptera	66.7	14.3	33.3	..	..	..	23.1	33.3	33.3	66.7	66.7	66.7
Coleoptera												
Dytiscidae	..	..	..	..	..	..	..	..	..	..	..	..
Hydrophilidae	..	..	..	..	..	..	..	..	..	..	..	..
Psephenidae	..	..	..	..	..	..	..	..	..	..	..	..
Elmidae	..	..	..	..	..	..	..	..	..	..	..	..
Diptera												
Tipulidae	..	..	..	..	..	..	7.7	..	..	..	..	..
Simulidae	..	..	..	..	..	..	..	..	..	..	16.7	..
Chironomidae	..	..	33.3	..	..	..	7.7	..	..	66.7	..	..
Ceratopogonidae	66.7	71.4	100.0	33.3	66.7	80.0	84.6	66.7	50.0	100.0	66.7	100.0
Others	..	..	..	..	..	..	..	..	..	..	..	..
Miscellaneous	..	..	..	16.7	..	..	7.7	..	..	..	..	33.3

TABLE 8.—Continued

Food Organism	Mean Number of Food Organisms Per Stomach											
	Big Creek											
	Jan. (13)	Feb. (12)	Mar. (9)	Apr. (11)	May (12)	June (7)	July (28)	Aug. (18)	Sept. (16)	Oct. (17)	Nov. (16)	Dec. (14)
Nematoda	..	0.08	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	0.33	..	..	..	..	..	..	..	..	..	0.07
Gastropoda	..	0.25	0.11	..	0.17	0.29	0.07	..	0.13	0.06	0.06	0.14
Arachnida												
Araneae	..	..	..	..	..	..	..	..	..	..	..	..
Acarina	..	..	..	..	..	0.14	0.04	0.11	..	..	..	..
Crustacea												
Cladocera	..	..	..	..	..	..	0.46	1.50	0.25	2.76	..	..
Ostracoda	..	..	..	..	..	0.57	1.46	1.11	0.19	0.12	..	..
Copepoda	0.23	0.83	..	0.09	0.25	0.29	0.29	0.11	0.75	1.18	2.25	0.86
Isopoda												
Asellidae	0.15	0.17	..	0.91	0.83	..	..	0.11	..	..	0.25	0.86
Amphipoda	0.54	1.50	..	2.27	..	0.29	0.07	0.06	..	0.35	..	0.14
Decapoda												
Astacidae	..	..	..	0.09	0.42	..	..	..	..	..	..	..
Insecta												
Plecoptera	0.54	0.08	..	0.09	..	..	..	..	..	..	..	0.36
Ephemeroptera	0.31	0.33	0.22	..	0.67	0.71	0.46	0.56	0.69	1.18	0.25	0.21
Odonata												
Zygoptera	..	0.08	..	..	..	..	..	..	..	..	..	..
Trichoptera	0.08	0.17	..	0.27	0.83	..	..	..	0.06	0.24	..	0.21
Coleoptera												
Dytiscidae	..	0.08	..	..	..	..	..	..	..	..	..	..
Hydrophilidae	..	0.08	..	..	0.08	..	..	..	..	..	..	..
Psephenidae	..	0.17	..	..	..	..	0.04	0.06	0.75	..	..	..
Elmidae	..	0.08	..	..	0.08	..	..	0.06	0.06	..	..	..
Diptera												
Tipulidae	..	..	..	..	..	..	..	..	..	..	..	..
Simulidae	..	..	..	..	..	..	..	..	..	..	..	..
Chironomidae	1.23	7.83	8.33	6.00	1.92	1.00	0.64	1.44	0.56	0.24	1.31	1.71
Ceratopogonidae	..	0.08	..	..	..	..	0.07	..	..	..	..	..
Others	0.08	0.17	..	..	..	..	0.11	..	0.06	0.06	..	..
Miscellaneous	..	0.08	..	2.23	..	..	..	..	..	..	..	0.07

Food Organism	Mean Number of Food Organisms Per Stomach											
	Ferguson Creek											
	Jan. (3)	Feb. (7)	Mar. (3)	Apr. (6)	May (6)	June (5)	July (13)	Aug. (6)	Sept. (6)	Oct. (3)	Nov. (6)	Dec. (3)
Nematoda	..	..	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	..	..	..	..	..	..	..	..	..	..	..
Gastropoda	..	0.29	..	..	..	..	..	..	..	..	..	..
Arachnida												
Araneae	..	..	..	..	..	0.20	0.15	..	0.17	..	..	..
Acarina	..	..	..	..	..	..	0.08	..	..	..	..	..
Crustacea												
Cladocera	..	..	..	..	..	..	3.08	..	..	..	..	..
Ostracoda	..	..	..	..	..	0.20	0.08	..	..	..	..	..
Copepoda	..	..	..	..	..	..	2.85	..	..	..	..	..
Isopoda												
Asellidae	..	0.14	0.33	1.00	0.17	..	0.08	0.17	..	..	..	1.00
Amphipoda	..	..	0.67	..	2.33	..	0.08	0.17	0.17	..	0.67	0.33
Decapoda												
Astacidae	..	..	..	..	..	..	..	..	..	..	..	..
Insecta												
Plecoptera	..	0.14	..	..	..	..	..	..	..	..	..	..
Ephemeroptera	0.33	..	..	..	0.17	0.20	0.08	0.33	..	1.33	0.67	0.67
Odonata												
Zygoptera	..	..	..	..	..	..	..	..	..	..	..	..
Trichoptera	0.67	0.14	0.33	..	..	..	0.69	1.33	0.50	1.67	5.17	1.67
Coleoptera												
Dytiscidae	..	..	..	..	..	..	..	..	..	..	..	..
Hydrophilidae	..	..	..	..	..	..	..	..	..	..	..	..
Psephenidae	..	..	..	..	..	..	..	..	..	..	..	..
Elmidae	..	..	..	..	..	..	0.08	..	..	..	..	..
Diptera												
Tipulidae	..	..	..	..	..	..	..	..	..	..	0.17	..
Simulidae	..	..	0.33	..	..	..	0.62	..	..	2.00	..	..
Chironomidae	1.33	8.86	7.33	1.67	6.17	5.40	4.77	1.00	5.83	17.00	4.50	3.33
Ceratopogonidae	..	..	..	..	..	..	..	..	..	..	..	..
Others	..	..	..	..	..	..	..	..	..	..	..	..
Miscellaneous	..	..	..	0.17	..	..	0.08	..	..	..	..	0.33

TABLE 9.—Stomach contents of *Etheostoma squamiceps* from Big and Ferguson creeks, by size class of darter. Figures in parentheses are numbers of stomachs examined.

Food Organism	Percent of Stomachs in Which Food Organism Occurred											
	Big Creek						Ferguson Creek					
	< 21 mm (10)	21–30 mm (41)	31–40 mm (43)	41–50 mm (57)	51–60 mm (16)	> 60 mm (6)	< 21 mm (7)	21–30 mm (10)	31–40 mm (17)	41–50 mm (14)	51–60 mm (14)	> 60 mm (5)
Nematoda	..	2.4	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	2.4	4.7	1.8	..	..	..	..	..	..	..	..
Gastropoda	..	2.4	7.3	8.8	12.5	..	..	..	..	..	7.1	20.0
Arachnida												
Araneae	..	..	..	..	..	..	..	20.0	..	7.1	..	..
Acarina	10.0	4.8	2.3	..	..	..	..	10.0	..	..	..	..
Crustacea												
Cladocera	30.0	22.0	4.7	1.8	..	..	42.9	..	..	..	..	..
Ostracoda	50.0	17.1	2.3	3.5	12.5	..	28.6	..	..	..	..	..
Copepoda	30.0	43.9	20.9	7.0	12.5	..	71.4	..	..	..	..	..
Isopoda												
Asellidae	..	7.3	9.8	8.8	37.5	16.7	14.3	..	17.6	14.3	14.3	20.0
Amphipoda	10.0	7.3	20.9	17.5	37.5	50.0	14.3	10.0	23.5	..	35.7	..
Decapoda												
Astacidae	..	..	..	1.8	12.5	16.7	..	..	..	..	..	..
Insecta												
Plecoptera	..	17.1	7.3	1.8	..	..	..	..	..	..	7.1	..
Ephemeroptera	30.0	29.3	27.9	45.6	31.3	16.7	28.6	10.0	11.8	28.6	28.6	..
Odonata												
Zygoptera	..	2.4	..	..	..	..	..	..	..	..	..	..
Trichoptera	..	12.2	2.3	5.3	6.3	..	..	10.0	58.8	14.3	42.9	..
Coleoptera												
Dytiscidae	..	..	..	1.8	..	..	..	..	..	..	..	..
Hydrophilidae	..	..	2.3	..	6.3	..	..	..	..	..	..	..
Psephenidae	..	7.3	2.3	1.8	6.3	..	..	..	..	..	..	..
Elmidae	..	4.8	..	1.8	..	..	14.3	..	..	..	..	..
Diptera												
Tipulidae	..	..	..	..	..	..	..	..	..	..	7.1	..
Simulidae	..	..	..	..	..	..	..	20.0	11.8	..	..	..
Chironomidae	70.0	56.1	72.1	36.8	43.8	50.0	100.0	90.0	82.4	64.3	50.0	40.0
Ceratopogonidae	..	..	4.7	..	..	..	..	..	..	..	..	..
Others	10.0	7.3	4.7	3.5	..	..	..	..	..	..	..	..
Miscellaneous	..	2.4	4.7	..	..	16.7	..	..	5.9	7.1	7.1	..

mined. A large variety of food organisms was found Tables 8 and 9). The predominant components of e diet of the Big Creek population were chironomid vae, mayfly naiads, copepods, amphipods, isopods, racods, and cladocerans, and of the Ferguson Creek pulation were chironomids, caddisflies, mayflies, phipods, and isopods.

Little seasonal variation in the diet was found Table 8). The use of cladocera, ostracods, and rina by juvenile *E. squamiceps* accounts for their esence in the diet during summer and early autumn d their absence in the rest of the year. The large pulations of small crayfishes in spring correlates h their appearance in stomachs of May- and ril-collected darters. The most commonly eaten ganisms, chironomids, were eaten in the largest numbers in the months immediately preceding spawning, presumably reflecting an increase in consumption associated with spawning preparedness.

The smallest darters examined fed predominantly on copepods, cladocera, ostracods, and chironomids; the largest darters fed mainly on amphipods, isopods, and chironomids in Big Creek, and on amphipods, chironomids, and caddisflies in Ferguson Creek (Table 9).

Aquarium-held *E. squamiceps* searched for food by moving over the gravel bottom in short, jerky movements. When a benthic organism was located, the darter approached closely, directed his snout toward it, and then quickly sucked it into his mouth. Nest-guarding males fed as readily as other individuals. Fry were successfully raised on brine shrimp.

TABLE 9.—Continued

Food Organism	Mean Number of Food Organisms Per Stomach											
	Big Creek						Ferguson Creek					
	< 21 mm (10)	21–30 mm (41)	31–40 mm (43)	41–50 mm (57)	51–60 mm (16)	> 60 mm (6)	< 21 mm (7)	21–30 mm (10)	31–40 mm (17)	41–50 mm (14)	51–60 mm (14)	> 60 mm (5)
Nematoda	..	0.02	..	..	..	..	..	..	..	..	..	..
Oligochaeta	..	0.02	0.07	0.02	..	..	..	..	..	..	..	..
Gastropoda	..	0.02	0.07	0.12	0.25	..	..	..	..	..	0.07	0.20
Arachnida												
Araneae	..	..	..	..	..	..	..	0.30	..	0.07	..	..
Acarina	0.10	0.05	0.02	..	..	..	..	0.10	..	..	..	..
Crustacea												
Cladocera	1.70	1.39	0.14	0.02	..	..	5.43	..	..	..	..	..
Ostracoda	2.70	0.63	0.02	0.25	0.13	..	0.29	..	..	..	..	..
Copepoda	0.80	1.68	0.51	0.11	0.13	..	5.14	..	..	..	..	..
Isopoda												
Asellidae	..	0.07	0.09	0.16	0.94	0.33	0.14	..	0.18	0.50	0.14	0.20
Amphipoda	0.10	0.10	0.37	0.28	1.00	1.83	0.14	0.10	0.65	..	0.79	..
Decapoda												
Astacidae	..	..	..	0.04	0.19	0.17	..	..	..	..	..	..
Insecta												
Plecoptera	..	0.22	0.07	0.02	..	..	..	..	..	..	0.07	..
Ephemeroptera	0.30	0.37	0.30	0.68	0.44	0.33	0.71	0.30	0.12	0.29	0.43	..
Odonata												
Zygoptera	..	0.02	..	..	..	..	..	..	..	..	..	..
Trichoptera	..	0.15	0.02	0.11	0.19	..	..	0.20	1.53	0.14	2.29	..
Coleoptera												
Dytiscidae	..	..	..	0.02	..	..	..	..	..	..	..	..
Hydrophilidae	..	..	0.02	..	0.06	..	..	..	..	..	..	..
Psephenidae	..	0.32	0.02	0.02	0.06	..	..	..	..	..	..	..
Elmidae	..	0.05	..	0.02	..	..	0.14	..	..	..	..	..
Diptera											0.07	..
Tipulidae	..	..	..	..	..	..	..	..	..	..	..	..
Simulidae	..	..	..	..	..	..	..	1.20	0.18	..	..	..
Chironomidae	1.10	2.29	4.07	1.44	0.75	0.83	8.14	12.00	5.82	4.64	1.21	1.00
Ceratopogonidae	..	..	0.07	..	..	..	..	..	..	..	..	..
Others	0.10	0.07	0.05	0.04	..	..	..	..	..	..	..	..
Miscellaneous	..	0.02	0.05	..	..	3.83	..	..	0.06	0.07	0.07	..

INTERACTIONS WITH OTHER ORGANISMS

Competition

E. squamiceps occurs syntopically with all other described species of *Catonotus*, demonstrating a lack of total competitive exclusion between *E. squamiceps* and any closely related (and described) species.

At the study areas, interspecific competition for habitat space seemed unlikely except possibly between *E. squamiceps* and *E. kennicotti* in the slab pools of Big Creek. In Ferguson Creek no other riffle-inhabiting darters occurred. In both Ferguson and Big creeks the slab pools generally had a small variety of fishes, and the species of *Catonotus* were almost always the most commonly occurring fishes.

The number of nesting sites of *E. squamiceps* and other slab-rock users in a given area was often great and seemed nearly to account for all available sites. Competition for these sites was somewhat reduced by the partial staggering of spawning periods. The sequence of spawning by the species known to spawn on the undersides of slab rocks in the study areas was, from earliest to latest: *Eurycea bislineata* (Amphibia), *Etheostoma squamiceps*, *Etheostoma kennicotti*, *Etheostoma obeyense*, and *Pimephales notatus*. No nests of *Etheostoma nigrum* were found although the species is known to spawn on the undersides of stones (Winn 1958*a*:205–206 and 1958*b*:176–180).

Predation

As potential predators nine *Esox americanus* and 12 *Lepomis cyanellus* collected with *E. squamiceps* from Big and Ferguson creeks were preserved and

ter examined for ingested *Catonotus*. One 121-mm *americanus* contained a recently ingested 44-mm *squamiceps*. No other evidence of predation was und.

arasitism

Both study populations of *E. squamiceps* were eavily parasitized by a spiny-headed worm, *Acanthocephalus jacksoni*. A total of 194 of these worms was removed from the intestines of 240 darters. The infestation was more severe in Big Creek (0.91 worms per darter) than in Ferguson Creek (0.53), and more severe in large darters (as many as 19 worms in a 69-mm male) than in small. In Ferguson Creek these worms were found only in darters collected from February through May and in August, but in

TABLE 10.—Characteristics of *Etheostoma squamiceps* (24 specimens), *E. kennicotti* (24 specimens) and a hybrid *squamiceps* x *E. kennicotti*, all from southern Illinois.

Characteristic	*E. squamiceps*			Hybrid	*E. kennicotti*		
	Range	Mean	Standard Deviation		Range	Mean	Standard Deviation
mber of lateral-line scales	48–54	50.5	2.0	46	39–46	42.6	1.8
mber of pored lateral-line scales	25–40	33.8	3.4	30	14–25	19.7	3.0
mber of scales around caudal peduncle	17–21	19.6	1.2	20	17–20	18.3	0.8
mber of vertical bands on caudal fin	6–9	7.6	0.8	7	8–11	9.3	0.8
mber of dorsal spines	7–9	8.3	0.6	8	6–8	7.2	0.5
mber of dorsal rays	12–14	13.0	0.4	13	11–13	12.1	0.5
mber of pectoral rays	10–12	11.1	0.4	12	11–13	12.0	0.2
ctoral fin length/standard length	0.21–0.25	0.23	0.01	0.26	0.23–0.28	0.25	0.01
inous dorsal fin base length/ standard length	0.21–0.24	0.23	0.01	0.23	0.23–0.28	0.26	0.01
inous dorsal fin base length/ soft dorsal fin base length	0.87–1.04	0.94	0.06	1.00	0.73–0.91	0.81	0.06
inous dorsal fin height/ soft dorsal fin height	0.50–0.86	0.62	0.08	0.54	0.44–0.55	0.47	0.03
inous dorsal fin height/body depth	0.35–0.52	0.46	0.05	0.39	0.35–0.43	0.39	0.02
pe squamation	Fully scaled			Partially scaled	Naked		
lly squamation	Fully scaled			Fully scaled	Variable naked strip		
rsal fin pigmentation	Without marginal band			Light marginal band	Distinct marginal band		
udal spots	Three black spots			Three black spots	No black spots		

TABLE 11.—Summary of life-history information on Big Creek and Ferguson Creek populations of *Etheostoma amiceps*.

Characteristic	Life-History Data
ncipal habitat of adults	Slab riffles in Ferguson Creek; slab pools in Big Creek
ncipal habitat of young	Slab riffles in Ferguson Creek; slab pools in Big Creek
e at reaching sexual maturity	1 year
e at first spawning	Females 1 year; males 2 years
e at reaching sexual maturity	Females about 35 mm; males about 40 mm
ual dimorphism	Males are larger, have longer fins and a deeper caudal peduncle, and in spring are much more boldly patterned
eeding tubercles	Absent
mber of mature ova counted	28–357
scription of egg in nest	1.8 mm in diameter, translucent, adhesive
wning period	From late March to May or early June
wning habitat	Slab pools
wning position	Both male and female briefly inverted, head to head
ting site	Underside of a slab stone
mber of eggs counted in nests	8–1500
guarding	Only by the male
ubation periods	270–275 hours at 18°–22° C, 125–130 hours at 22°–26° C
uence of sex on growth rate	By the third year males are significantly larger than females
sity	Up to 9.6 darters/m² in slab riffles in Ferguson Creek; up to 2.0 darters/m² in slab pools in Big Creek
ratio among young	1.7 females: 1 male in Ferguson Creek; 1.3 females: 1 male in Big Creek
gevity	3+ years
imum size	72 mm standard length
rations	To and from spawning grounds
ritoriality	Extreme in breeding males; weak in females and nonbreeding males
ncipal diet	Aquatic insect immatures and crustaceans

Big Creek worms were found in darters collected in every month except June, July, and August. *A. jacksoni* has previously not been known to parasitize *Etheostoma* (Hoffman 1967:283).

The only ectoparasites found were two piscicolid leeches attached to the caudal fins of two young *E. squamiceps* collected in Big Creek in October.

Hybridization

No accounts of hybridization involving *E. squamiceps* were listed by Schwartz (1972). One *E. squamiceps* x *E. kennicotti* hybrid male was collected in Big Creek on 1 October 1971. The specimen measured 40 mm, was 1+ years old, and shared morphological characteristics with both parent species (Table 10).

SUMMARY

The life-history information on *E. squamiceps* collected in Big and Ferguson creeks between 6 October 1970 and 19 June 1973 is summarized in Table 11.

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A BIBLIOGRAPHY OF THE

NORTHERN CORN ROOTWORM, *Diabrotica longicornis* (Say), and the WESTERN CORN ROOTWORM, *Diabrotica virgifera* LeConte (Coleoptera: Chrysomelidae)

W. H. Luckmann · H. C. Chiang · E. E. Ortman · Martha P. Nichols

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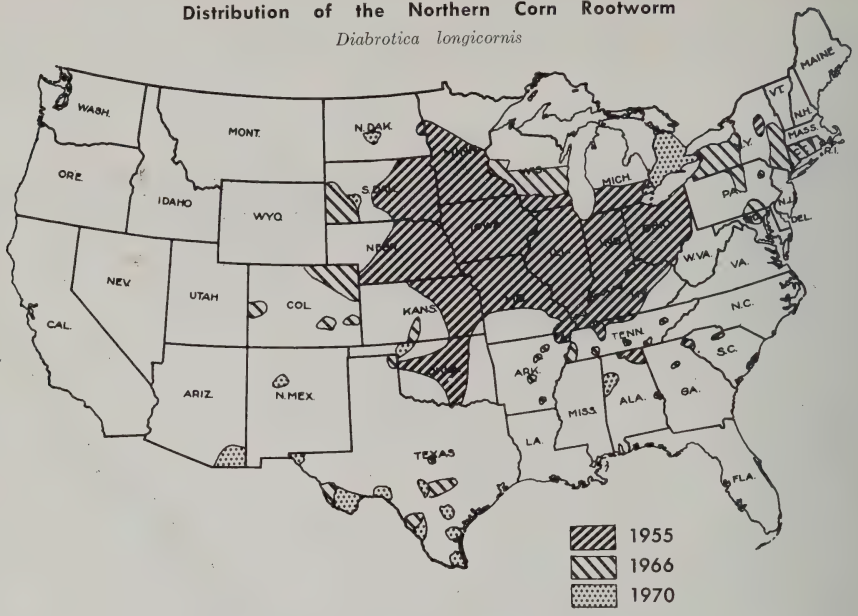
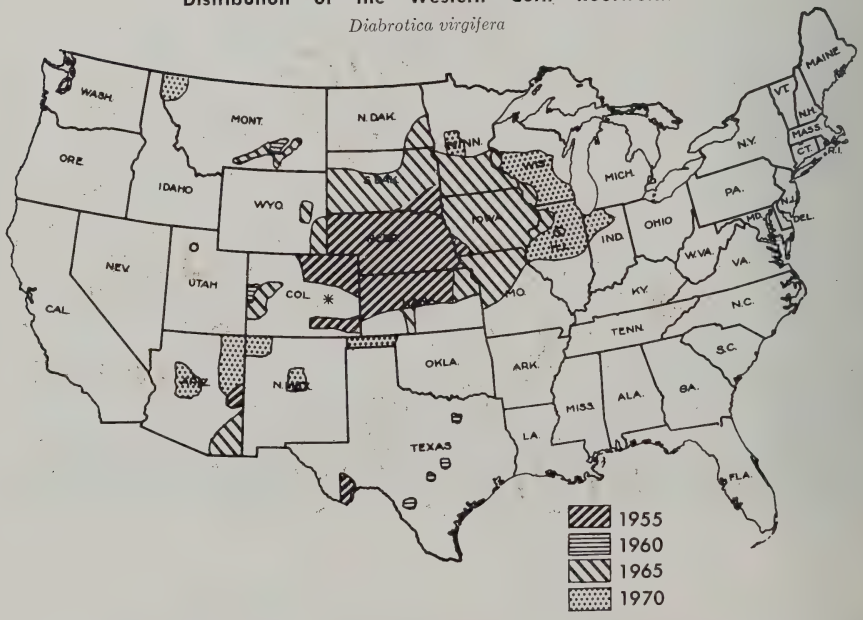
Distribution of the Northern Corn Rootworm

Diabrotica longicornis



Distribution of the Western Corn Rootworm

Diabrotica virgifera



COVER ILLUSTRATION — Northern corn rootworm adult (lower left) and western corn rootworm adult (upper right). Photo by Wilmer Zehr.

A BIBLIOGRAPHY OF THE NORTHERN CORN ROOTWORM AND THE WESTERN CORN ROOTWORM

W. H. Luckmann, H. C. Chiang, E. E. Ortman, and Martha P. Nichols

This bibliography is limited to papers dealing with the northern corn rootworm, *Diabrotica longicornis* (Say), and the western corn rootworm, *Diabrotica virgifera* LeConte. The 426 titles in the present list were obtained primarily from standard reference sources and the personal files of the authors.

The northern corn rootworm and the western corn rootworm are major pests of corn in the corn belt region of north-central USA. Distribution extends beyond this area, but damage by the larva is usually negligible south of latitude 30° N. The northern corn rootworm is most abundant in North America in an area roughly extending from latitude 37° to 45° N and longitude 80° to 100° W. The western corn rootworm is dispersing to the east and it is currently most abundant in an area roughly extending from latitude 40° to 45° N and longitude 85° to 105° W. Numerous isolated infestations of each species occur beyond these general boundaries south to the Mexican border and into Ontario, Canada, with new infestations reported each year. The two species are indigenous to North America.

The western corn rootworm is a product of modern agriculture. It intensified as a problem in irrigated corn in Nebraska about 30–40 years ago. Up to 1955, the western corn rootworm was found only in Nebraska and portions of Colorado, Kansas, South Dakota, and western Iowa. Since then it has moved eastward and northward into major corn-producing states. It developed resistance to the cyclodiene soil insecticides in the 1950's and the distribution of the resistant strain expanded northward and eastward.

The biology and behavior of the two species are very similar. In nature, corn is probably the only host, though it has been shown experimentally that the immatures of both species can develop to varying degrees on certain other species of grasses. Adults feed on the pollen, silks, and kernels of corn and on the fruiting structures of many other plants, including weeds.

The northern and the western corn rootworms have only one generation per year. Most eggs are laid in August in the soil in cornfields. The eggs are usually concentrated in the rows at the base of the corn plants in nonirrigated fields and between rows in fields with irrigation. Most eggs of the northern corn rootworm will be deposited in the upper few inches of soil. Ovipositional behavior of the western corn rootworm is slightly different, as females oviposit many of their eggs between the plant rows and eggs are often deposited at a greater depth in the soil. Following oviposition, eggs develop slightly and diapause through fall and winter. In the corn belt area of the USA the eggs begin to hatch in June and the first adults appear in July. Some eggs will not have hatched by the time the first adults appear. Thus, the egg stage lasts about 10 months, although, experimentally, a few eggs of the northern corn rootworm have been shown to go through two winters.

The larvae feed on corn roots and concentrate near the base of the plant. The larvae consume the roots, decreasing nutrition supplied to the ear, and in strong wind and rain storms plants with moderate to severe root damage may become lodged. The duration of the larval plus pupal stages is about 1 month. In laboratory cages, adult rootworm females will live about 2 months and oviposit for about 3 weeks, during which time they will deposit about 300–350 eggs. In the field, adult life probably does not exceed 5–6 weeks. There is a preoviposition period of 2–2½ weeks. Northern corn rootworms are very difficult to maintain in the laboratory, and culturing has not been very successful. The western corn rootworm can be cultured in the laboratory, but the egg diapause does not permit continuous mass rearing.

The adults may remain for a considerable time in the field where they emerge. Later they disperse, seeking pollen in late-maturing fields, alfalfa, and ornamental plants. Northern corn rootworm adults congregate on silks and in tips of ears of corn, whereas western corn rootworm adults have less tendency to congregate and they will be found on other parts of the plant as well as the ears. Thus counts made in ear tips will show a predominance of northern corn rootworm adults, whereas casual visual counts in the same field and at the same time show a predominance of western corn rootworm adults.

Northern corn rootworms and western corn rootworms live together and have similar habits, and there is some interaction between the two species. Several researchers have reported a displacement of the northern corn rootworm by the western corn rootworm. Interspecific matings have been observed in the fields, and F_1 progeny of crosses were produced in the laboratory. The F_1 adults have the phenotype of the western corn rootworm.

Larvae of northern corn rootworms and western corn rootworms are resistant to the cyclodiene insecticides over much of their range. Organophosphate and carbamate soil insecticides applied at planting time are used for control. Rotating corn with other crops is a positive means of control. Usually, only the larvae are damaging, but adults congregating and feeding on fresh silking ears

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can interfere with pollination, and in these instances insecticides are applied for adult control.

The brief introduction above, providing some general information about the western corn rootworm and the northern corn rootworm was written to assist the student and the researcher. All references in the bibliography were examined, except those preceded by the symbol #. A "Listing of References by Rootworm Species" has been included, following the numbered bibliography entries, so that users of the bibliography will be able to tell readily which of the numbered papers deal with which species of corn rootworms. A list of abbreviations used in the bibliography appears at the end of the paper.

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LISTING OF REFERENCES BY ROOTWORM SPECIES

I. Northern corn rootworm, *Diabrotica longicornis* (Say)

4, 14, 17, 19, 21, 25, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46, 47, 58, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 88, 91, 93, 96, 98, 99, 100, 101, 102, 104, 107, 112, 114, 116, 117, 118, 119, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 135, 137, 138, 139, 141, 142, 143, 145, 147, 148, 154, 155, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 178, 179, 180, 189, 194, 195, 196, 197, 198, 199, 207, 208, 211, 212, 214, 215, 216, 217, 218, 219, 220, 222, 223, 224, 225, 229, 234, 235, 237, 238, 240, 241, 243, 249, 250, 251, 252, 254, 255, 256, 257, 258, 259, 264, 267, 268, 269, 270, 271, 272, 273, 278, 285, 286, 293, 295, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 318, 319, 320, 321, 323, 324, 325, 326, 327, 328, 329, 331, 333, 334, 336, 337, 338, 339, 340, 342, 343, 344, 346, 347, 348, 349, 352, 353, 354, 355, 357, 358, 359, 361, 363, 364, 369, 370, 371, 372, 374, 375, 376, 377, 378, 379, 380, 381, 382, 384, 385, 386, 387, 388, 389, 392, 393, 394, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 413, 416, 417, 418, 420, 422, 423, 424.

II. Western corn rootworm, *Diabrotica virgifera* LeConte

1, 4, 14, 17, 18, 21, 23, 28, 30, 31, 33, 35, 37, 42, 44, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 64, 77, 80, 81, 82, 83, 84, 85, 86, 87, 89, 90, 93, 94, 95, 97, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 114, 115, 116, 117, 121, 122, 123, 124, 125, 126, 127, 128, 130, 133, 135, 136, 143, 147, 148, 149, 152, 153, 154, 170, 171, 172, 173, 174, 176, 177, 178, 179, 180, 183, 185, 186, 187, 188, 189, 190, 191, 192, 193, 195, 196, 197, 198, 199, 200, 202, 203, 204, 205, 206, 207, 208, 209, 211, 212, 213, 214, 215, 217, 219, 220, 221, 222, 223, 226, 227, 228, 229, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 244, 247, 248, 250, 251, 256, 257, 258, 261, 263, 267, 269, 270, 273, 275, 278, 282, 284, 287, 288, 289, 291, 293, 294, 295, 296, 297, 298, 299, 301, 303, 312, 313, 315, 318, 319, 330, 334, 335, 336, 337, 341, 343, 344, 345, 346, 347, 348, 349, 350, 351, 355, 359, 360, 362, 363, 364, 365, 366, 367, 368, 370, 372, 373, 374, 375, 376, 378, 379, 381, 382, 383, 385, 386, 387, 388, 392, 393, 394, 406, 407, 408, 410, 411, 412, 413, 414, 415, 416, 418, 420, 422, 424, 425, 426.

III. *Diabrotica* spp.

2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 20, 22, 24, 26, 32, 45, 69, 92, 113, 120, 134, 140, 144, 146, 150, 151, 156, 157, 175, 181, 182, 184, 201, 210, 230, 231, 245, 246, 253, 260, 262, 265, 266, 274, 276, 277, 279, 280, 281, 283, 290, 292, 314, 316, 317, 322, 332, 356, 390, 391, 395, 396, 397, 419, 421.

PERIODICAL ABBREVIATIONS

Agr. Chem. — Agricultural Chemicals.
Agr. Tec. Mex. — Agricultura Tecnica en Mexico.
Agrichem. Age —Agrichemical Age.
Agway Coop. — Agway Cooperator.
Amer. Entomol. — American Entomologist.
Ann. Entomol. Soc. Amer. — Annals of the Entomological Society of America.
Annu. Rev. Entomol. — Annual Review of Entomology.
Breeder's Gaz. — Breeder's Gazette.
Bull. Entomol. Soc. Amer. — Bulletin of the Entomological Society of America.
Bull. Ill. State Natur. Hist. Surv. — Bulletin of the Illinois State Natural History Survey.
Can. Entomol. — Canadian Entomologist.
Can. J. Genet. Cytol. — Canadian Journal of Genetics and Cytology.
Coleopt. Bull. — Coleopterists' Bulletin.
Colo. State Entomol. Circ. — Colorado State Entomologist Circular.
Commer. West — Commercial West.
Conn. Agr. Exp. Sta. Bull. — Connecticut Agricultural Experiment Station Bulletin.
Coop. Econ. Insect Rep. — Cooperative Economic Insect Report (USDA).
Co-op Grain Quart. — Co-op Grain Quarterly.
Country Gent. — Country Gentleman.
Crop Qual. Counc. Ext. Conf. Rep. — (Exact source unknown).
Crop Sci. — Crop Science.
Crops & Soils Mag. — Crops and Soils Magazine.
Doane's Agr. Rep. — Doane's Agricultural Report.
Entomol. Soc. Ont. Annu. Rep. — Entomological Society of Ontario Annual Report.
Ext. Serv. Rev. — Extension Service Review.
FAO Plant Prot. Bull. — FAO (Food and Agriculture Organization of the United Nations) Plant Protection Bulletin.
Farm Chem. — Farm Chemicals.
Farm J. — Farm Journal.
Farm Quart. — Farm Quarterly.
Folia Entomol. Mex. — Folia Entomologica Mexicana.
Geigy Agr. Chem. — Geigy Agricultural Chemicals.
Ill. Agr. Exp. Sta. Annu. Rep. — Illinois Agricultural Experiment Station Annual Report.
Ill. Agr. Exp. Sta. Bull. — Illinois Agricultural Experiment Station Bulletin.
Ill. Dep. Agr. Circ. — Illinois Department of Agriculture Circular
Ill. State Entomol. Annu. Rep. — Illinois State Entomologist Annual Report.
Iowa Agr. Exp. Sta. Circ. — Iowa Agricultural Experiment Station Circular.
Iowa Farm Sci. — Iowa Farm Science.
Iowa State Coll. Agr. Ext. Serv. Pamph. — Iowa State College Agricultural Extension Service Pamphlet.
Iowa State Coll. J. Sci. — Iowa State College Journal of Science.
Iowa State Univ. Coop. Ext. Serv. Pamph. — Iowa State University Cooperative Extension Service Pamphlet.
Irrig. Farmer — (Exact source unknown).
J. Acad. Natur. Sci. Philadelphia — Journal of the Academy of Natural Sciences of Philadelphia.
J. Agr. Food Chem. — Journal of Agricultural and Food Chemistry.
J. Agr. Res. — Journal of Agricultural Research.
J. Amer. Soc. Agron. — Journal of the American Society of Agronomy.
J. Econ. Entomol. — Journal of Economic Entomology.

J. Insect Physiol. — Journal of Insect Physiology.
J. Invertebr. Pathol. — Journal of Invertebrate Pathology.
J. Kans. Entomol. Soc. — Journal of the Kansas Entomological Society.
J. Minn. Acad. Sci. — Journal of the Minnesota Academy of Science.
Kans. Agr. Exp. Sta. Dir. Rep. — Kansas Agricultural Experiment Station Director's Report.
Kans. Farmer — Kansas Farmer.
Ky. Agr. Exp. Sta. Bull. — Kentucky Agricultural Experiment Station Bulletin.
Mem. Entomol. Soc. Can. — Memoirs of the Entomological Society of Canada
Mich. Agr. Exp. Sta. Quart. Bull. — Michigan Agricultural Experiment Station Quarterly Bulletin.
Mich. State Bd. Agr. Annu. Rep. — Michigan State Board of Agriculture Annual Report.
Mich. State Univ. Coop. Ext. Serv. Ext. Bull. — Michigan State University Cooperative Extension Service Extension Bulletin.
Minn. Agr. Ext. Fact Sheet Entomol. — (Exact source unknown).
Minn. Farm Home Sci. — Minnesota Farm and Home Science.
Minn. Sci. — Minnesota Science.
Miss. Ext. Serv. Circ. — Mississippi Extension Service Circular.
Mo. Agr. Exp. Sta. Bull. — Missouri Agricultural Experiment Station Bulletin
N. C. Dep. Agr. Bull. — North Carolina Department of Agriculture Bulletin
N. Dak. Farm Res. — North Dakota Farm Research.
Nebr. Agr. Exp. Sta. Annu. Rep. — Nebraska Agricultural Experiment Station Annual Report.
Nebr. Agr. Exp. Sta. Bull. — Nebraska Agricultural Experiment Station Bulletin.
Nebr. Agr. Exp. Sta. Ext. Circ. — Nebraska Agricultural Experiment Station Extension Circular.
Nebr. Agr. Exp. Sta. Quart. — Nebraska Agricultural Experiment Station Quarterly.
Nebr. Exp. Sta. Quart. — Nebraska Experiment Station Quarterly
Nebr. Farmer — Nebraska Farmer.
Nebr. State Bd. Agr. Annu. Rep. — Nebraska State Board of Agriculture Annual Report.
Nebr. State Entomol. Bull. — Nebraska State Entomologist Bulletin.
Ohio Agr. Exp. Sta. Bull. — Ohio Agricultural Experiment Station Bulletin.
Ohio Agr. Res. Develop. Center Res. Circ. — Ohio Agricultural Research and Development Center Research Circular.
Ohio Rep. Res. Develop. — Ohio Report on Research and Development.
Ohio State Univ. Agr. Ext. — Ohio State University Agricultural Extension.
Ont. Dep. Agr. Food Fact Sheet AGDEX — Ontario Department of Agriculture and Food, Fact Sheet AGDEX.
Pestic. Inst. News — The Pesticide Institute News.
Plant Dis. Rep. — Plant Disease Reporter.
Pract. Entomol. — Practical Entomologist.
Proc. Acad. Natur. Sci. Philadelphia — Proceedings of the Academy of Natural Sciences of Philadelphia.
Proc. Annu. Hybrid Corn Ind.-Res. Conf. — Proceedings of the Annual Hybrid Corn Industry-Research Conference (American Seed Trade Association).
Proc. Entomol. Soc. Wash. — Proceedings of the Entomological Society of Washington.
Proc. Indiana Acad. Sci. — Proceedings of the Indiana Academy of Science.
Proc. N. Cent. Br. Amer. Assoc. Econ. Entomol. — Proceedings of the North Central Branch of the American Association of Economic Entomologists.
Proc. N. Cent. Br. Entomol. Soc. Amer. — Proceedings of the North Central Branch of the Entomological Society of America.
Proc. Symp. Physiol. Ecol. Plants Anim. Extreme Environ. — Proceedings of the Symposium on Physiological Ecology of Plants and Animals in Extreme Environments, Dubrovnik, Yugoslavia.
S. Corn Impr. Conf. Rep. — Report of the Southern Corn Improvement Conference.
S. Dak. Farm Home Res. — South Dakota Farm and Home Research.
S. Dak. State Coll. Agr. Ext. — South Dakota State College of Agriculture Extension.
Trans. Amer. Entomol. Soc. — Transactions of the American Entomological Society.
Trans. Amer. Soc. Agr. Eng. — Transactions of the American Society of Agricultural Engineers.
25th Corn Sorghum Res. Conf. — 25th Corn and Sorghum Research Conference.
U.S. Commr. Agr. Annu. Rep. — United State Commissioner of Agriculture Annual Report.
U.S. Dep. Agr. Agr. Handb. — United States Department of Agriculture, Agriculture Handbook.
U.S. Dep. Agr. Bull. — United States Department of Agriculture Bulletin.
U.S. Dep. Agr. Div. Entomol. Bull. — United States Department of Agriculture, Bureau of Entomology, Bulletin.
U.S. Dep. Agr. Bur. Entomol. Circ. — United States Department of Agriculture, Bureau of Entomology, Circular.
U.S. Dep. Agr. Div. Entomol. Bull. — United States Department of Agriculture, Division of Entomology, Bulletin.
Univ. Calif. Publ. Entomol. — University of California Publications in Entomology.
Univ. Ill. Coop. Ext. Serv. Circ. — University of Illinois Cooperative Extension Service Circular.
Univ. Nebr. Agr. Ext. Serv. — University of Nebraska Agricultural Extension Service.
Va. J. Sci. — Virginia Journal of Science.
Va. Polytech. Inst. Ext. Leafl. — Virginia Polytechnic Institute Extension Leaflet.
Wis. Agr. Exp. Sta. Bull. — Wisconsin Agricutural Experiment Station Bulletin.

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